AD-A031 367 PITTSBURGH UNIV PA PROGRAMMED LEARNING LAB F/G 5/9
A GUIDE TO THE PREPARATION OF PROGRAMMED INSTRUCTIONAL MATERIAL--ETC(U)
OCT 62 J I TABER, R GLASER, H H SCHAEFER AF 33(616)-7175

UNCLASSIFIED NL

1 OF 3
AD
A031367

F 3

367

FG

2

6

A GUIDE TO THE PREPARATION OF PROGRAMMED INSTRUCTIONAL MATERIAL

10

Julian I. Taber
Robert Glaser
with
Halmuth H. Schaefer
and the assistance of
Nancy A. Hoisman

15

Produced under contract AF 33(616)-7175 add
sponsored by
Training Research Branch
Behavioral Sciences Laboratory
USAF
Ross L. Morgan, Technical Monitor

11 October, 1962 12 213p.

New 409898

3 Programmed Learning Laboratory
Department of Psychology
University of Pittsburgh
Pittsburgh 13, Pennsylvania

Robert Glaser, Project Director
James H. Reynolds, Assistant Project Director

General Contents

Part I. Introduction

Chapter 1. Introductory Overview 1

Part II. Principles of Learning: Definitions and Operations

Chapter 2. Definitions and Operations in Learning and Instruction . . 21

Chapter 3. Stimulus Control of Behavior. 41

Part III. Programming Procedures

Chapter 4. Analysis of Instructional Objectives and Subject Matter Units 67

Chapter 5. The Frame Unit and Prompting Techniques 85

Chapter 6. Frame Sequences and Program Characteristics 119

Chapter 7. The Programming Enterprise 151

Part IV. Research and Development

Chapter 8. Implications for Research, Development, and the Conduct of Training 183

A detailed Table of Contents follows on Page iii.

PREFACE

The present interest in teaching machines and programmed instruction is specifically attributable to the writings of Professor B. F. Skinner in 1955 and 1958.[1] Other work on instructional technology was also being reported at that time, such as the contributions from military and other sources[2] and Pressey's "testing" machines had previously appeared. However, it is Skinner's work which has captured the general imagination, and his transition from laboratory studies to practical application that has encouraged a systematic basis for further necessary research and development. The language and technology of Skinner's laboratory that provided the framework for the first programmed materials.

Initial developments spring into being with the errors and ineffciencies of first inventions, as, for example, the Wright Brothers' airplane. However, these first developments, if they are at all exciting, provide a basis for continued development and correction and a target for constructive revision. With this in mind, the attempt has been made in this guide to present the major principles that contributed to these first steps in programmed instruction and which have led to present practices and can shape their improvement. These early attempts pertained to what can be called verbal, linear, small-step programming, although the general principles involved are not restricted only to verbal behavior or to this type of format. Subsidiary practices, developed away from the main stream are described in this guide, but the attempt has been made to provide a sustained point of view, at least as far as possible.

---

[1] Skinner, B. F. The science of learning and the art of teaching. In Current trends in psychology and the behavioral sciences. Pittsburgh: University of Pittsburgh Press, 1955.

Skinner, B. F. Teaching machines. Science, 1958, 128, 969-977.

[2] Lumsdaine, A. A. & Glaser R. Teaching machines and programmed learning. Washington, D. C.: National Education Association, 1960. Part II.

At the present stage of development of programmed instruction, there is little substitute for research, development, and demonstration. These efforts, however, must take place on the basis of underlying principles and not outward appearances. Programmed instructional materials have distinctive formats, but are based on underlying ideas. The improperly initiated practitioner may learn only to imitate the format and ignore the principles. It is for this reason that this guide discusses principles as well as procedures. Procedural prescriptions alone, at this stage of development, lead to extreme rigidity and inefficiency.

Part I of this guide is an introduction to the major characteristics and purposes of programmed instruction, Part II continues with a description of principles of learning, Part III goes on to practical programming procedures, and Part IV discusses implications for research, development, and operational activities. For special purposes, these parts can be read as units in themselves. Of course, there is no substitute for the practical effort of constructing, testing, and revising programmed materials, and this guide should serve only to prompt this behavior.

This guide was initiated with Dr. Felix Kopstein as project monitor. During the preparation of the present revised guide, Dr. Ross Morgan served in this capacity. Ruth Ann Rishel provided the excellent secretarial skills necessary for final production.

TABLE OF CONTENTS

Part I. Introduction

1. Introductory Overview . . . 1

    Reinforcement . . . 2

    Defining Instructional Objectives . . . 3

    Program Characteristics . . . 4

        Gradual Progression to Establish Complex Repertoires . 4
        Prompting . . . 9
        Fading and Vanishing . . . 10
        Confirmation and Scoring . . . 13
        The Observing Response . . . 13
        Practice and Review . . . 13
        Understanding and Discrimination . . . 15
        Measuring and Improving Program Effectiveness . . . 16

    Machines and Instrumentation . . . 17

    Educational Psychology and Instructional Practice . . . 17

    The Plan of this Book . . . 18

Part II. Principles of Learning: Definitions and Operations

2. Definitions and Operations in Learning and Instruction . . . 21

    Behavior as Observable Events . . . 22

Stimuli . . . 23

    The Stimulus Control of Behavior . . . 23

Responses . . . 24

    Approximating a Desired Response . . . 24

    Response Repertoires . . . 25

Reinforcement . . . 28

        The Learner's Response to the Reinforcing Stimulus . . 29
        Immediacy of Reinforcement . . . 29

    Characteristics of Reinforcers (Reinforcing Stimuli) . . . 30

        Positive Reinforcers . . . 30
        Negative Reinforcers . . . 31
        Punishers . . . 31

Secondary Reinforcement 32

Reinforcement in Education and in Programming 33

Extinction 35

Extinction Contrasted to Admonition and Persuasion . . 35
Extinction Contrasted to Punishment 36
Extinction and Response Substitution in Programmed Learning 36

Spontaneous Recovery and Warm-Up 37

Summary 38

3. Stimulus Control of Behavior 41

Discriminative Behavior 41

Establishment of Stimulus Control 43

Sharpening of Control 46

Extension or Expansion of Control 47

Consolidation of Control 48

Discrimination and Differentiation 50

Stimulus Generalization 53

Response Chaining and the Integration of Behavior 55

The Process of Response Chaining 57

Experimental versus Educational Techniques for Building Response Chains 59

The Nature of Reinforcement in Chained Behavior 61

Motivational Uses of Terminal Behavior 63

Summary 65

Part III. Programming Procedures

4. Analysis of Instructional Objectives and Subject Matter Units 67

Defining Objectives for Programmed Materials 67

A General Procedure 68

Specifying Steps and Sequences in a Program 71

The Ruleg System 71
Subdivision of Subject Matter Units 74
Discrimination Flow 76
Mathetics 79

Task Taxonomies 80

Instructional Sequence of Tasks 82
A General Taxonomy 83

Summary 84

5. The Frame Unit and Prompting Techniques 85

The Frame Unit 85

Behavioral Requirements of a Frame 86

Reinforcement at the Frame Level 89

The Role of Prompts in a Frame 89

A General Classification of Prompts 91

Formal Prompts 94

The Copy Prompt 94
The Partial Response Prompt 95
The Literal Prompt 96
Structural Prompts 99

Thematic Prompts 102

The Pictorial Prompt 103
Context-Setting Prompts 103
Semantic Prompts 104
The Analogy Prompt 108
The Eliminator Prompt 109
Association Prompts 110
The Rule Prompt 113
The Example Prompt 114

Withdrawal of Prompts 115

Summary 117

6. Frame Sequences and Program Characteristics 119

Special Frame Sequences 119

Introductory Frame Sequences 119

Discrimination Sequences 122

Generalization Sequences 125

Chaining Sequences 126

Drill Sequences 133

Review Sequences 133

Terminal Behavior Sequences 136

Sequences Using Extra-Frame Materials 137

Panel Sequences 137
Extraction and Embedding Sequences 137
Programmed Note-Taking 138

Types of Programs 139

Linear Programs 139

Branching Programs 140

Intrinsic Programming 140
Multi-Track Programs 141

Response Mode 147

Summary 149

7. The Programming Enterprise 151

Personnel 151

Program Director 151

Programmers 152

Non-Professionals as Programmers 152
Subject Matter Experts as Programmers 153
Psychologists as Programmers 153

Subject Matter Specialist 154

Training Specialist 154

Editors 155

Psychological Editing 155
Linguistic Editing 156
Subject Matter Editing 156

Make-Up Director 156

Subjects 157

The Role of Subjects in Tryout 157
Selecting Tryout Subjects 158

Setting Up for Production 159

Specifying Terminal Behavior 159

Setting Up the Enterprise 160

Programmer Training 161

Initial Steps in Training 161
Editorial Marks 161
Trying Out Programming Techniques 165

Program Production 166

First Editing 166

First Program Tryout 168

Second Editing and Processing 169

Preparing the Program Format 169

Programmed Textbook Format 169
Useful Formulas in Making Up A Programmed Textbook 171
Other Printed Formats 175

Final Tryout 177

The Program Manual 178

Specification of Objectives 178
Program Prerequisites (Entering Behavior) 179
Program Validity 179
Test Conditions and Student Sample 179
Program Effectiveness 180
Administrative Considerations 180

Summary 181

Part IV. Research and Development

8. Implications for Research, Development, and the Conduct of Training 183

Problems for Research and Development 183

The Instructional System 183

Terminal Behavior (Instructional Goals) 185

Entering Behavior 186

Instructional Sequences 186

Size of Step 187
Programming Richness of Experience 188
Analysis of Knowledge and Task Structure 188
The Form of Student Response 189
Retention of Basic Skills 190
Rate of Learning 190
Response Feedback and Reinforcement 191

Performance Assessment 192

Individual Differences and Aptitude 193

Machines, Automation, and Simulation 195

Prototype Model Instructional Systems 196

Operational Considerations For An Instructional System 196

Training Objectives 197

Training Input 197

Instructional Procedures 198
Performance Assessment 199
Technology in Training 200
Conclusion 201

PART I

INTRODUCTION

Chapter 1: Introductory Overview

A variety of teaching machines, programmed textbooks, and other self-tutoring devices have been developed in the past few years, creating a great deal of interest on the part of educators, training specialists, scientists and the public. Despite superficial differences, the best of these devices are founded on certain basic assumptions about how learning takes place, and they attempt to make use of the same fundamental operations to accomplish learning. Most programmed learning methods present the subject matter in a series of steps called frames which require an active response from the student. Each step or frame is typically constructed so that it is highly probable that the student will make the correct response. Sequences of frames are designed specifically to bring about learning by gradually leading the student to make more and more sophisticated responses on his own. Moreover, all programmed learning devices provide some kind of feedback or correction so that the student is informed of his performance after each response

The most important characteristic of programmed learning is that it applies what is known about learning to educational psychology. This point correctly implies that, for the most part, educational psychology and training methodology have not attempted to base their practices on modern developments in the science of learning. In recent years, however, an increasing number of experimentally and learning-theory oriented psychologists have been working on educational and training problems. The approaches to problems employed by these individuals and their reports of success and failure in applying the methods and knowledge of their science have important implications for training and education in general.

A number of schools, colleges, and industrial and military training organizations have also been stimulated by the apparent control of the educational process that programmed learning and automated teaching methods offer. Many of these organizations are in the midst of experimenting with radical curriculum changes--not so much in subject-matter content, but with respect to the teaching of it. As a result, it appears

that programmed materials can teach many subject matters more effectively than they are taught at the present time. Moreover, these new techniques can be evaluated more carefully than other educational procedures. In contrast to a textbook or lecture, the effectiveness of programmed material can be determined by a detailed analysis of the learner's behavior. This permits numerous improvements to be made in the course of developing programmed materials, as well as making it possible to evaluate program effectiveness in an instructional situation.

At the present time, it is generally recognized that the success of a teaching machine is largely a function of the material used in it. The construction of this material is the most difficult and crucial task in the development of programmed instructional procedures. This handbook is concerned, therefore, with the principles and practices underlying the construction of programmed learning sequences rather than with hardware or machines. These programming principles represent an application of learning theory to programmed teaching. As a student goes through a learning program, certain of his initially unskilled responses are strengthened and shaped into subject matter competence. Programming rules are concerned with how to induce such behavioral changes.

Reinforcement

Present knowledge of the learning process points out that behavior is acquired and modified through the operation of "reinforcement." Briefly, reinforcement is the occurrence of an event (for example, a reward) following a response which serves to strengthen and maintain the response. The salient feature in modifying behavior is making the reinforcement or reward dependent upon the performance of the learner. By "rewarding" relatively minute behavioral changes, it is possible to strengthen certain of the learner's responses and lead him in small steps from his initial behavior to far more complex behaviors. This modification should take place in small enough steps so that the student's progress and motivation are not jeopardized by frequent failures. In most current instructional programs, the reinforcing agent is knowledge of results, that is, knowledge about whether the learner's response is considered correct.

A great number of responses must be learned in acquiring complex behavior, such as a new language or knowledge of electronics. The number of reinforcements and the arrangements for reinforcement required to establish such complicated behavior overtax the time and skill of the most efficient instructor, especially within the limits of the usual classroom or training situation. For this reason, instructors often employ educational materials such as textbooks, manuals, and outside work, to assist in teaching complex behavior. When such aids are used, however, it is not possible for the teacher to carefully monitor and shape student behavior. Instructional programming is an attempt to provide for the careful guidance of learning that is necessary. It is concerned with the precise selection and arrangement of educational material based upon what is known about human learning. The term programming refers to the process of constructing sequences of instructional material in a way that maximizes the certainty of learning and retention, and enhances student motivation. It is a process which an effective tutor may use intuitively. The hope is that an effective programmer may someday be able to program certain subject matters according to definable rules.

Defining Instructional Objectives

A first step in programming is defining the objectives of instruction. The programmer must know just what terminal behavior he wants the student to engage in at the end of the program. He must be able to specify the kinds of subject matter material the student will learn to respond to in the course of this performance. The primary purpose of instruction is to provide the student with a behavioral repertoire comprising "knowledge of the subject matter." If the repertoire is elementary electronics, a program must lead to the acquisition of the specific student performances which define this kind of knowledge.

Defining and specifying the terminal behavior or goal of instruction is no trivial problem. With the control possible by means of programmed learning sequences, specific statements must be made concerning the form of the knowledge skills that are to be learned. Should instruction in mathematics, for example, enable the student to solve problems, apply his

knowledge to new problems, prove theorems, or all three of these? The form of a learning program can differ radically as a function of the criterion behavior chosen. The behavioral end products of instruction must be specified in objective, concrete terms in order to permit the construction of effective learning sequences. This can often be accomplished by constructing a detailed achievement or proficiency test of the behavior to be taught.

Program Characteristics

Gradual Progression to Establish Complex Repertoires. In developing complex performance, a program reinforces and strengthens any available student behavior which is a slight approximation to the terminal behavior. The program then builds upon this behavior in subsequent steps in order to reinforce and strengthen a small change which is in the direction of the terminal repertoire. Thus a program moves in finely graded steps or frames, working from simple to higher and higher levels of subject matter complexity. This gradual progression permits the student to be correct as often as possible and is an efficient way to develop new patterns of behavior.

An example of gradual progression can be seen in the following items or frames from a junior high school general science program. These frames illustrate some typical programmed materials and might be presented either in textbook form or in a teaching machine. Each frame exposes the student to a small amount of material which is designed to encourage him to respond. Before he begins the program, the student would be told to either fill in the blanks or write his answers on a separate answer pad. The frame below is the twenty-ninth frame in a program on measurement and the metric system.

29. In the Metric System, we use something called a meter in place of a yard. The English System uses a yardstick where the Metric System uses a ______stick to measure with.

As soon as he responds, the student turns the page or advances the machine, revealing the correct answer, "meter" or "meterstick," against which he checks his response. Then, the student turns the page or advances the machine and looks at the next frame, number 30.

30. A meter is slightly longer than a yard. A yard is slightly ________ than a meter.

The student again responds, checks to see if his answer is the correct one, "shorter," and moves on to the next frame, 31.

31. It is easy to learn about the Metric System when one thinks about our money system in relation to it. A dollar has _____ cents (pennies). A meter has the same number of centimeters that a dollar has cents. A meter has _____ centimeters.

Learning that a yard is slightly shorter than a meter and that a meter contains 100 centimeters is not very astonishing in itself. In a 250 frame program, however, these small steps gradually and systematically result in a substantial amount of learning. At the beginning of the learning sequence, instructional stimuli are used to evoke behavior already in the repertoire which the student brings to the teaching situation. Frames 29 and 30, for example, both call for responses the student can already make. During the course of instruction the student learns new stimulus-response combinations. Each step requires behavior the student is capable of performing, however, and thus permits the student to take each step with a high probability of success. The learning process involves this gradual transfer of behavior to new subject matter stimuli. Towards the end of the instructional sequence, more and more frames call upon these gradually built up skills. Frame 101 is an example of a frame which appears late in the sequence on the metric system.

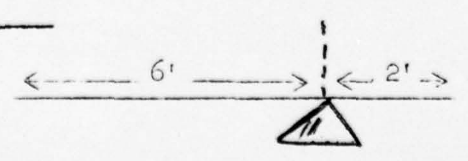
101. 7 kilometers = ____ meters.
8 kilometers = ____ centimeters.
9 kilometers = ____ millimeters.

Figure 1 is a further illustration of gradual progression in a learning program. This consecutive sequence of frames was taken from the middle of an eighth grade program on work and machines. This particular section of the program is designed to teach the student methods for finding the mechanical advantage of simple machines and expands the student's previous learning about simple machines.

Figure 1

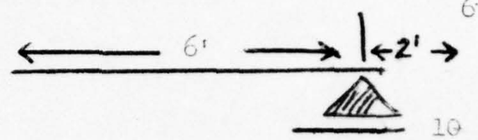
Gradual Progression in a Programmed Learning Sequence on Work and Machines

Frames	Responses
The increase in force that a machine gives us is caused by its mechanical advantage (MA). The mechanical advantage is the cause of the ________ in force which the machine gives us when we do work	increase
Most machines help us do work. Therefore, most machines have a ____________ advantage.	mechanical
The increase in force that we get from a machine is its ____________ ____________.	mechanical advantage
Most __________ have a mechanical advantage.	machines
If a machine helps us lift twice as much weight, it has a mechanical advantage of 2 (twice as much). A machine which enables us to lift 4 times as much as a mechanical advantage of _____.	4
A machine which enables us to lift five times as much has a mechanical advantage of _____.	5
If a lever has a mechanical advantage of 6, it will increase our force 6 times. If a lever has a mechanical advantage of 7, it will increase our force _____ times.	7
Mechanical advantage (MA) can be calculated for a machine The MA of a lever is the length of one end divided by the length of the other end. For example, 6 feet ÷ 2 feet. $MA = \frac{6}{2}$, the MA of this lever is _____	3

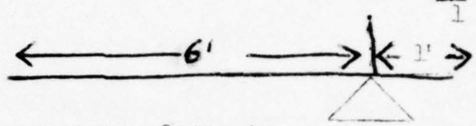


(Figure 1 continued)

The lever pictured has an MA of 6 ÷ 1. It will increase our effort (force) _____ times. 6



This lever has an MA of $\frac{?}{?}$ = _____. $\frac{10}{1} = 10$



A lever with an MA of 10 should increase our force to _____ times the original force. 10

Prompting. A programmed sequence begins by calling only for relevant student behavior which is available at the outset. The problem is to get the student to make new responses with a minimum of errors. Before behavior can be reinforced and strengthened, however, it must be emitted, and instructional material has to be designed to elicit the correct and appropriate behavior which then can be appropriately reinforced.

The occurrence of desired behavior in a program can be made more probable by the use of formal hinting and coaching techniques which are based upon what is known or can be safely assumed about the student's verbal behavior. Such techniques are illustrated in the following sample frames designed to teach the Greek prefixes for numbers.[1]

> The student is to acquire the correct use of mono, di, tri, tetra, penta, etc., under the control of numerical aspects of verbal and non-verbal stimuli--e.g., pictured polygons, or the subscripts in chemical notations. Existing connections in the student's repertoire can be exploited, going first from Greek to English, as in "The Decalogue is another name for the ____ Commandments," or "A monocle is a lens for use in only _____ eye." The student can then complete familiar and later unfamiliar expressions by substituting the Greek prefixes ... as in "The five-sided building in Washington used by the Army is called the ______gon," or "People who make a practice of having only one wife or husband are called ______gamous," or "A line of poetry having six feet is called ________meter." From such general material the student can then be transferred to a specific application--as in being asked to compose the technical names for chemical compounds indicated with symbols ("CF_4 is carbon ________fluoride") or to write the symbols for compounds named, "Osmium octafluoride is written __________."

[1]This example is from Skinner, B. F. The programming of verbal knowledge. In E. Galanter, (Ed.), Automatic teaching: the state of the art. New York: Wiley, 1959. Pp. 67-68.

Prompting and cuing techniques, then, play an important role in the progression through a program. They help in controlling error, in evoking behavior, and in bringing this behavior under the control of new stimuli. It is obvious that such techniques may often be the stock in trade of a master teacher. However, the objective in programming is to make these techniques as explicit and non-intuitive as possible.

Fading and Vanishing. Thus far it has been indicated that programming techniques elicit behavior through prompting and strengthen behavior through reinforcement and gradual progression. Another principle in programming is fading or vanishing. These terms refer to the gradual removal of prompts so that a student responds only to the stimulus material which will be available when he performs the "real" task; when he is on his own, so to speak, and learning crutches have been eliminated. The systematic progression of programmed learning is well set up to accomplish this elimination of cues.

The following description indicates how a student can learn to recite a poem in a programmed learning sequence and illustrates the technique of fading.[2]

> The student must read the line "meaningfully" and supply the missing letters. The second, third, and fourth frames present succeeding lines in the same way. In the fifth frame, the first line reappears with other letters also missing. Since the student has recently read the line, he can complete it correctly. He does the same for the second, third, and fourth lines. Subsequent frames are increasingly incomplete, and eventually--say, after 20 or 24 frames--the student reproduces all four lines without external help, and quite possibly without having made a wrong response. The technique is similar to that used in teaching spelling: responses are first controlled by a text, but this is slowly reduced (colloquially, "vanished") until the responses can be emitted without a text, each member in a series of responses being now under the "intraverbal" control of other members.

---

[2] From Skinner, B. F. Teaching machines. Science, 1958, 128, 972.

Figure 2 presents an example of fading or vanishing from a junior high school program on electricity. Over 500 frames have preceded this sequence and the student has already learned that an atom consists of electrons, protons and neutrons. He has also used the word "electron" in association with the word "negative." The first frame in the figure prompts the response strongly by means of a copying prompt; that is, the response is copied from the stimulus material in the frame. Fading begins in frame 531. The response here is prompted by being set in opposition to positive protons. This is a much weaker cue than that used in frame 530. Frame 532 is even less prompted and again makes use of the antithetical association of positive and negative. Frame 533 cues the student by means of the first letters of the response words. The last two frames give the student minimal prompting and require him to respond, for the most part, on his own.

Figure 2

Fading and Vanishing in a Programmed Learning Sequence in Electricity

530.	Electrons have a negative charge of electricity. The part of the atom with a negative (-) charge is the ________.	electron
531.	Protons have a positive (+) electrical charge. All ________ have a positive electrical charge, all electrons have a ________ electrical charge.	protons negative
532.	All ________ have a positive electrical charge; all ________ have a negative charge.	protons electrons
533.	Neutrons are neutral--that is, they have <u>no</u> electrical charge. P________ have a <u>positive</u> charge, e________ have a <u>negative</u> charge, n________ have no charge.	protons electrons neutrons
534.	________ have a <u>positive</u> charge. ________ have a <u>negative</u> charge. ________ have <u>no</u> charge.	protons electrons neutrons
535.	The part of the atom with no charge is the ________.	neutron

Confirmation and Scoring. As has already been indicated, an important characteristic of programmed learning is that the student receives information regarding the correctness of his response. It is generally assumed that confirmation can provide appropriate reinforcement and that it will motivate the student to work carefully in order to come up with the correct answer at each step. In most present programs the student makes a response and then judges whether he is right or wrong by comparing his response with the correct one shown in the program. It is also possible, however, for a machine to be more fully automated so that it senses and scores the correctness of a response.

The Observing Response. Immediate confirmation then, "encourages a more careful reading of programmed material than is the case in studying a text, where the consequences of attention or inattention are so long deferred that they have little effect on reading skills."[3] This behavior of observing or attending is produced by the structural arrangement of the program. When immediate reinforcement is forthcoming, a student will be more likely to learn how to concentrate on specific features of a presentation. The constant attention to the subject matter which a program demands will not permit the development of competing habits of distractibility. Less controlled methods of teaching than a program, however, may allow distractible behavior to occur more frequently.

Practice and Review. A program must contain a certain amount of review and repetition in order to maintain previous learning and to strengthen concepts which are weak or which will be called upon in further learning. Figure 3 shows a consecutive series of frames from the early part of a program, designed to get a response highly practiced so that it can be used in further learning. The response "ten" is elicited a number of times in this sequence so that it will be highly practiced when further discussion of the metric system occurs.

---

[3]From Skinner, B. F. Teaching machines. Science, 1958, 128, p. 975.

Figure 3

A Practice Sequence from a
Junior High School Program on Measurement

The reason for this is that the Metric System is based on one key number and that is the number ten (10). In the Metric System, everything depends on the number _____.	ten
The English System depends on many different numbers including 1, 3, 12, 36, 32, 16 and many more. The Metric System is easier to work with than the English System because it does not use all these numbers, but rather it uses only the number _____ as its base.	ten
Our dollar system is something like the _____ System. One dollar is the equivalent of _____ dimes.	Metric ten
One ten dollar bill is the equivalent of _____ dollars.	ten
Our money system and the _________ _________ are both based on the number _____.	Metric System ten

Sufficient practice and overlearning are necessary so that early material is thoroughly mastered before or while new material is introduced. With fading and with the omission of lessons as they are mastered, a systematic transition can be made from old to new concepts by means of review and repetition. Concepts not otherwise involved in a particular sequence of items can be reviewed periodically. Programmers use the word "seeding" to describe the scattering of review materials at various points in a program so as to insure the maintenance of learning.

Since unvaried repetition can be extremely annoying, repetition in a program should be continuously varied both in context and pattern. When the program contains such variation, the student receives new information, learns to make finer discriminations, and learns to apply what he has learned to a wide variety of situations.

Understanding and Discrimination. Subject matter materials have not been fully mastered until the student can use them in varied contexts. For example, a student cannot be presumed to have thoroughly learned the concept "noun" until he has worked with material that requires him to distinguish between nouns and verbs. This kind of discrimination is involved in the formation of concepts. A programmed learning sequence can provide a well-organized series of examples by which the student is led to develop abstractions and complicated concepts.

The important goal in teaching is to enrich the student's understanding by making him permute and recombine the elements of his behavior.[4] The programmer or a good instructor is not concerned with the student's response to any one situation except as a sample of an abstraction. Rather than learning a uniform and explicit verbal response repertoire about a concept, the student should acquire a repertoire which is applicable in a variety of situations. Thus he can use the concept to solve problems, describe the concept to others, modify it for specific purposes, build

---

[4] From Skinner, B. F. The programming of verbal knowledge. In E. Galanter (Ed.), Automatic teaching: the state of the art. New York: Wiley, 1959. Pp. 63-68.

a model of it, and so forth. When he can make such a variety of appropriate responses, it can be said that he understands a concept. A learning program in contrast to rote drill, can lead to the acquisition of a conceptual repertoire because the behavioral elements which constitute the repertoire are called out in a variety of patterns and contexts.

Measuring and Improving Program Effectiveness. Programs must be evaluated by means of carefully developed achievement and proficiency tests. These test situations should measure the defined terminal behavior in terms of stimulus material generally agreed to be relevant to the task. However, the knowledge acquired by the student is only one aspect of the effectiveness of a programmed learning sequence; efficiency of teaching is also important. A student in a lecture and a student working on a teaching machine may learn the same things, but the student using the machine may take much less time. This would suggest that program effectiveness should be evaluated in relation to time required for learning as well as in terms of obtained proficiency.

The detailed feedback available to the programmer concerning program effectiveness is a very important aspect of a program. If students do not learn, the program needs to be modified. The editing and revision of instructional material thus becomes an empirical matter in which the teacher learns from the behavior of the learner. Each successive revision of a programmed learning sequence insures that student performance will be brought closer and closer to the defined terminal behavior, i.e., the educational objectives of the program. Many educators who have tried their hands at building and using programs for their own students have discovered that the repeated revision is in itself an extremely valuable training aid for the instructor. The detailed analysis of the student's interactions with the program provides considerable insight into the processes of teaching and learning.

Machines and Instrumentation

At the present time the development of a technology of programming subject materials appears to be a more important task than the development of machines as such. This current emphasis is prevalent largely as the result of the following factors: (a) initial programming efforts were accomplished with verbal printed materials; (b) for the most part, materials have been tried out on age levels at which students can read and write; (c) the response feedback employed permits the individual to judge for himself the correctness of his response; (d) programs have attempted to be optimally useful for many individuals, i.e., not written for one individual; and (e) beginning attempts have employed simple machines whose functions could be accomplished by non-machine formats.

There are, however, numerous possibilities for using machines. One example is in the teaching of non-verbal and motor skills, such as the ability to estimate distances or to work a lathe. Machines might also permit the use of programs at age levels where only pre-verbal skills and relatively imprecise responses are available. In addition, automation seems useful for programs in which it is difficult for the student to judge the adequacy of his response. It is possible that response feedback should consist of more than an indication of correctness, such as guiding the student, depending upon his previous response. Any such attempts to individualize programs so that they are more finely adjusted to individual repertoires would seem to require automation in order to implement the required display and control functions. In general, the present emphasis on programming as such should be interpreted as a stage of development in instructional programming. The potential for machine instrumentation should be concurrently under development.

Eduational Psychology and Instructional Practice

The development of programmed instruction has reflected one dominant idea: that teaching and learning, as behavioral phenomena, can be made subject matters for scientific study, on the basis of which a technology of instruction can be developed. More important than the role of devices and programs themselves is the fact that programmed instruction forces the educator and training specialist to become explicit both about their

instructional goals, and the processes they employ as means of attaining these goals. The research and development so far are only the beginning of the effort necessary to implement the consequences of this point of view and to develop a technology of instructional methods. While it is impossible to predict the outcomes of future investigations, it seems certain that identification of the instructional variables which permit behavior modification will continue to be the heart of effective attempts to improve education and training. Research on these instructional variables is the basis on which the systematic development of teaching machines and programmed instruction must proceed.

As research and development continue, the focus of attention may shift away from the specific considerations and instructional techniques which are at present thought to be most important. Future research may alter current ideas, and techniques may be changed as well. The basic conception will stand, however, that instruction and learning are amenable to systematic description and improvement through experimental inquiry. The significance of the approach represented by programmed instruction lies primarily in this assumption, rather than in specific characteristics of programmed materials as they currently exist or in any theoretical points that underlie current efforts.

The Plan of this Book

The chapters in this book are an attempt to present both the underlying principles of behavior that are related to instructional programming, and the practical techniques which can be specified on the basis of present knowledge and experience. Chapters 2 and 3 introduce some major concepts and operations in learning and instruction derived from the behavioral scientist's laboratory. These concepts apply to learning situations in general and provide a basis for understanding many of the techniques of programming. Since programming is at such a relatively early and unsettled stage of development, familiarity with basic learning operations provides a basis for the innovational and imaginative use of specific programming rules. Chapters 4, 5, and 6 elaborate on the major procedures and characteristics of programming: the specification of program objectives, frame characteristics, frame sequence types and program characteristics. These

chapters describe some techniques currently in use and provide illustrative material. Chapter 7 outlines the tasks involved in a team approach to program construction and points up some of the problems and considerations in program development. Chapter 8 summarizes the status of programmed instruction and indicates needed research and development. Some considerations in implementing programmed materials in an instructional setting are also discussed.

PART II

PRINCIPLES OF LEARNING: DEFINITIONS AND OPERATIONS

Chapter 2: Definitions and Operations in Learning and Instruction

From the point of view of the psychologist, all learning involves the modification of behavior. The instructor's goal is to change the nature of the student's behavior with respect to a given subject, event or object. His teaching techniques are all attempts to increase the probability that the student will make a particular kind of response to a certain subject matter. When the student has learned to add, for example, his response to "5 + 7" has changed from any number of inappropriate statements such as "5 cross 7" or "5 ex 7," and inappropriate activities such as scribbling or singing, to the appropriate response, "12." As a result of having learned to add, "12" is a response to "5 + 7" that has become highly probable or exists at high strength. Put another way, the stimulus "5 + 7" has come to control the student's behavior.

The primary contribution of the science of behavior to training and education is the premise that behavior is controlled by specifiable circumstances. While many of the characteristics of behavior and principles of behavior modification were first observed in the laboratory, they are applicable to human behavior outside the laboratory. This chapter and the next describe some behavioral principles which are useful both to the psychologist studying the behavior of his subjects and the educator attempting to modify the behavior of his students.

A major reason for including a discussion of basic principles in this manual is that the technology of programmed learning is still relatively undeveloped. It is highly probable, therefore, that the techniques of programming will change to a much greater extent than the underlying principles on which programming is based. Since the field is new and expanding rapidly, techniques must be kept flexible and opportunity should be presented for ingenuity and innovation. The instructor who is familiar with the principles of behavior can make use of programmed instruction and other teaching procedures intelligently and effectively. Instead of rigidly using certain instructional techniques, he can employ his knowledge of learning principles to integrate specific procedures into a generally effective learning environment. It seems far more desirable to teach the

instructor how to arrange the learning environment than to leave the matter up to chance or to less than certain devices. The exposition and explanation of principles of behavior should make possible the optimal use of programmed learning and effective management of the learning situation.

The principles for behavior modification to be described here are quite general and need not be restricted to programmed instruction. The behavior of the student does not suddenly become subject to different principles of learning the moment he puts away his program or teaching machine. The more efficient learning of desirable behaviors that occurs with a program in contrast to the ordinary classroom situation is due to the carefully prearranged learning situation a program provides. Just as programs are effective because of the consistent and well-planned application of learning principles, so the non-programmed situation, such as the tutor-student relationship, can be far more effective than usual when the instructor understands the conditions which control the behavior of the student.

Behavior as Observable Events

In a science of behavior and in a technology for training, the popular meanings of such words as "personality," or "conduct" are too general to be of use. The psychologist uses the term "behavior," to refer to the overt and measurable activity of an organism. The distinction between what can be seen of an individual's actions and what is inferred by an observer is especially important in the management of behavior. The overt, specific and measurable actions of the individual are the data of a science of behavior and the building blocks of a practical technology. Through the study of observable behavior it has been possible for psychologists to begin to understand such complex forms of behavior as problem solving and thinking. Similarly, in training and education it is through the guidance of observable actions that the instructor can influence such apparently covert performances.

Stimuli

A stimulus (pl: stimuli) is any condition, event, or change in the environment of an individual which produces a change in behavior. Food may be a stimulus to eat, the command, "come here," may serve as a stimulus for movement, or the word "dangerous," printed in red letters may serve to abruptly change a person's ongoing behavior. A major task in building a programmed learning sequence is the careful arrangement of the subject matter stimuli to which the student will respond.

The term "stimulus" is seldom used abstractly, but refers to a specific event which calls out specific behavior. A stimulus is that aspect of the environment which is responsible for producing the behavior; it is not necessarily that which appears to an observer to be responsible. For example, a child may "read" the word yellow by giving the teacher the correct vocal response when the word is shown, but the child may be responding only to the letters "LL" or "OW" alone. The child may have learned to respond correctly to different words on the basis of only a few features of each word. The teacher would be incorrect in assuming that the child responds only to those aspects of the stimulus situation which he as a teacher discriminates.

The Stimulus Control of Behavior

When an individual responds in a certain way to a given stimulus, that stimulus can be considered to control behavior. The number of stimuli that control or determine behavior increases with maturity. A very young child's behavior is determined by relatively few and primarily internal stimulus conditions, e.g., hunger, pain, or thirst. As he matures, the child responds to more and more external stimuli. The development of complex forms of behavior is possible because of an individual's increasing responsiveness with maturity to new sources of stimulation.

For the most part, new stimuli are added to those which already control behavior by means of learning. Thus an effective learning sequence is an arrangement for the acquisition of new controlling stimuli. Since a technology for education is concerned with the manipulation of subject matter stimuli in the environment of the learner, an instructional process first requires the identification of those stimuli which currently control the behavior of the learner, and then the placement of these stimuli under the management of the teacher.

Responses

A response is a unit of behavior and the building block of complex performances. The flick of an eye and the twitch of a finger are examples of simple responses; eating, walking, speaking, and reading are all instances of somewhat more complex responses. A primary objective of educational technology is the guidance of an individual's responses. To accomplish this objective, the instructor must first define and enumerate the components of the performance that he wishes to produce. It is then possible to arrange the stimulus conditions which will result in the correct response. It also becomes possible to develop objective measures of the amount and accuracy of the occurrence of the response.

The consequences of a student's response are extremely important in learning. The events which follow the occurrence of a response have an effect upon future behavior. Examples of such response consequences are reward, punishment and knowledge of results. The reward or other stimulation provided to the organism immediately after responding is a significant factor which seems to determine whether learning takes place. The occurrence of consequences of behavior that are effective in producing and maintaining behavior is technically called reinforcement. In an educational situation, the instructor controls the consequences of the student's behavior. Since these consequences determine whether the student learns, the teacher will want to maximize those consequences which facilitate learning.

Approximating a Desired Response

The instructor's decision to reward or not reward a student's response is usually based upon whether the response meets a specified criterion. In learning complex behavior, however, the student's initial responses will be variable and quite crude and will rarely meet the instructor's criterion of competence. The effective instructional procedure is to tolerate the student's initially crude responses and gradually take him towards mastery in very small steps. This makes it possible to maximally reward the student during the course of instruction, i.e., for him to be maximally successful. Training then becomes a matter of reducing permissible error tolerances for the learner's responses. For example, a person may make many attempts to

toss a penny into a cup. In approximating accuracy, the size of the cup (i.e., the size of error tolerance) can be decreased gradually as accuracy increases. From the learner's point of view, any particular attempt is either a success or a failure. From the trainer's point of view, however, the permissible error tolerance at any stage of training is only one value or set of values along a continuous scale of measurement which results in specific consequences for the learner.

One way to establish a new response, then, is by gradually contracting the permissible margin of error. If the goal, for example, were to teach precise tempo to a student of music, it would be unrealistic to reward the student only on those rare occasions when he briefly maintained a precise tempo. Since any beginning student will be quite variable in his performance of a task, error tolerances should be initially large. Error tolerances should be contracted at a rate which keeps the probability of student error very low. Each range of permissible or acceptable behaviors should include a major portion of the range of variations in the student's performance so that there will be frequent opportunity to reward the student for successful performance. With time, the range of observed performances will align itself with the particular range of acceptable performance in force. As the student's behavior approximates what is required, it becomes possible to further restrict the criteria. A sudden and unrealistic constriction of performance criteria, however, will immediately decrease the student's successes and if sufficiently great will result in the loss of student interest.

Response Repertoires

In actuality, any given behavior of an individual is complex and made up of many kinds of simple responses depending on the nature of the behavior and the level of skill of the individual. Several responses which are logically or functionally related may be grouped together and referred to as a "repertoire." Thus the responses involved in performing a task such as typing or solving equations or dealing with words constitute different repertoires of behavior. An individual's total behavior can be considered to consist of a wide variety of such response repertoires.

Consider, for example, two kinds of complex behavior, reading and swimming; for different purposes, these behaviors can be classified in various ways. When an individual has learned to read and swim, he has learned to respond appropriately--that is, his responses are under appropriate stimulus control. Both swimming and reading can be considered discriminative repertoires because a swimmer or a reader can discriminate the correct stimuli for his responses from other, incorrect stimuli. From another point of view, swimming and reading can be described as serial repertoires because the numerous discriminative responses involved occur in an ordered series. To be able to swim, the individual must perform his responses in a specific sequence. In reading sentences, the reader must follow a series of words.

The stimuli for reading are in the form of words and combinations of words in sentences. Thus, reading makes use of both verbal and interverbal response repertoires. Swimming, on the other hand, is non-verbal behavior and can be considered a motor-skill repertoire. The stimuli to which a reader responds are discrete or separate symbols and a reader's responses to words occur in discrete units. In this sense, reading can be functionally classified as a discrete repertoire. In contrast, swimming involves smooth, continuous and sequential responses and, therefore, can be considered a continuous response repertoire. In swimming, moreover, each response or muscle movement serves as a stimulus for the next response--the swimmer sustains his own discriminative behavior through such response-produced stimulation. Thus swimming is also a self-sustained repertoire. Similarly, reciting a poem from memory would be a self-sustained repertoire.

With respect to an instructional situation, an individual can be considered to have an entrance and a terminal repertoire. The entrance repertoire refers to whatever pertinent behavior the individual brings to the learning situation. The terminal repertoire is the behavior which the student should acquire from the instructional situation and is the reason for undertaking instruction. Usually, students bring at least some elements of the terminal repertoire to the instructional situation and this behavior may be used in the teaching process to attain the instructional objectives.

Thus a child learning to read already speaks the language and knows the alphabet. A beginning swimmer, likewise, has years of practice in walking, moving his arms, and coordinating his body movements.

The term repertoire, then, is used to describe the nature of the responses which are involved in performing particular kinds of complex behavior. To summarize, a discriminative repertoire is a collection of related behaviors which are elicited by specific environmental conditions--in short, any learned behavior. When the stimuli to which the individual responds are in an ordered sequence, the responses can be considered to also form a serial repertoire. If the sequence of stimuli are produced by responses the individual makes himself, his behavior can be described as a self-sustained repertoire. Responses to discrete stimuli can be said to comprise a discrete repertoire, while responses to continuously variable stimuli can be said to comprise a continuous repertoire. These specific types of repertoires are arbitrary and neither exhaustive nor mutually exclusive categories. They should serve, however, to illustrate some ways in which behavior can be classified and described.

A distinction should be made between the terms repertoire and knowledge. Repertoire emphasizes the behavior of an individual, while knowledge focuses on the subject matter and its characteristics and content. Although musical knowledge connotes a vast body of information about music, a musical repertoire would be a description of the behaviors demonstrated by a student of music. The notion of a response repertoire implies attention to specific behaviors which have been or are to be learned. Just as a response may be brought under the control of environmental situations, so entire repertoires of responses may come under control of subject matter stimuli. The instructional process is concerned with bringing specific repertoires under the control of subject matter stimuli in specific areas of knowledge.

Determining the types of repertoires to be taught in a given instructional situation serves to indicate the instructional approach required. Moreover, differences among some repertoires are indicative of differences in level of training. Discriminative, serial and self-sustained repertoires, for example, may describe different levels of proficiency from novice to expert. Thus with a discriminative repertoire, an individual can identify

and respond to a stimulus. A serial repertoire indicates that the individual can also perform the discriminations in an ordered sequence. With a self-sustained repertoire, the individual can perform serial discriminations on his own without support from the stimulus environment.

Reinforcement

The consequences of an organism's actions are critical in the modification and maintenance of behavior. Behavior is acquired (or modified) under conditions in which a response produces a consequent stimulus event (such as a reward) that strengthens or maintains that response. The stimulus event which the response produces is referred to as a "reinforcer" or "reinforcing stimulus." The occurrence of a reinforcer as a consequence of behavior is called reinforcement. When a parent makes sure that a child's desirable performance is rewarded or reinforced with a cookie (the reinforcer), that parent has provided reinforcement.

The arrangement of an environment that will yield certain stimuli (reinforcing stimuli) only when specified behaviors occur, is the process of providing reinforcement. For example, in training a dog to obey a command, a dog trainer will give the dog a small portion of food whenever he performs the desired behavior, i.e., the trainer reinforces the dog with food. The giving of such a reward is a reinforcement, the food itself is a reinforcer. Human beings are similarly affected by the consequences of their behavior. Praise, promotions, grades, and money may all serve to reinforce or strengthen human behavior. In the example above, the dog's correct responses reinforce the trainer and strengthen his tendency to train the dog.

The reinforcing consequences of behavior may arise from the behavior itself, as eating cake leads to a pleasant taste, or may arise from the environment, as asking a question prompts someone else to give an answer. While most behavioral consequences occur naturally, reinforcement in the educational setting is a deliberately arranged consequence of behavior. A teaching machine, for example, is a deliberate and somewhat artificial arrangement for the student to gain immediate feedback for his performance.

The Learner's Response to the Reinforcing Stimulus. The most important general point about reinforcers is that they are stimuli. They are parts of the environment which are produced as a result of an individual's behavior. In addition, they are stimuli to which the individual makes a strong and rather consistent response. A reinforcer or reinforcing stimulus is effective as such precisely because it elicits a predictable and vigorous response from an organism. It is the organism's existing response to food, for example, that makes food an effective reinforcer in teaching other behavior. The strength of this existing response to a reinforcing stimulus is, in a sense, a measure of the power of the reinforcer to bring about further learning.

In the laboratory, a strong response to a reinforcing stimulus, such as food, can be assured by depriving the organism of the stimulus for a period of time prior to the training session. In a similar way, it is possible to insure that a human will find social approval rewarding by withholding such approval prior to its use as a reinforcer. Attention and approval, if lavishly given, become useless as rewards for good conduct. It follows from the above that a reinforcing stimulus may have differing levels of potency depending upon the individual's immediately prior exposure to it, i.e., whether he is satiated or has been deprived. Over an interval of time, the effect of various reinforcers on an individual may be expected to fluctuate as the individual's periods of satiation and deprivation fluctuate.

Immediacy of Reinforcement. The effect of a reinforcer in strengthening behavior is on the immediately preceding behavior. Therefore a reinforcer must immediately follow the response to be learned. If the reinforcer is delayed, the desired response may never be learned (although other responses might be). A close temporal relationship between a reinforcer and the behavior to be reinforced is essential for the occurrence of learning.

Characteristics of Reinforcers (Reinforcing Stimuli)

Most of the reinforcing stimuli described so far have been external or environmental stimuli, such as food. Reinforcing stimuli may also be internal to the organism, however. Many important rewards and punishment seem to be inherent in behavior. Often, for example, the process of responding seems to be reinforcing in itself--the individual shows "joy of doing." Thus, the teacher need not always arrange explicit environmental reinforcers; simply arranging for the occurrence of a new behavior may frequently be sufficient to maintain that behavior for some time thereafter. More will be said later concerning responses themselves as reinforcers. In general, however, a reinforcer is any stimulation arising from the environment or from behavior itself which is a consequence of behavior and may be used to modify, shape, or maintain performance.

While no single terminology or classification system is generally agreed upon by psychologists, for present purposes reinforcing stimuli can be discussed in terms of positive reinforcers, negative reinforcers, and punishers. Before comparing their differences, certain characteristics of reinforcers in general should be repeated. First, all reinforcers are stimuli which arise either from the environment or from behavior itself. Second, all reinforcers bear a close temporal relationship to the reinforced response. Third, all reinforcers elicit a strong and consistent response from the organism involved. Finally, reinforcers have an effect upon behavior and may be used to modify or maintain an organism's behavior.

Positive Reinforcers. A positive reinforcer is any stimulus which an individual will work to obtain. When produced as a consequence of a response, a positive reinforcer serves to strengthen and maintain the response. Examples of positive reinforcers include consumable stimuli such as food and water, as well as culturally derived stimuli such as praise and money. Immediate confirmation with the correct answer can frequently be used as a positive reinforcer in programmed learning. In addition to immediate knowledge of results, positive reinforcers such as outstanding accomplishments, teacher praise, and the tangible products of a newly acquired response, may also be useful in an educational situation.

Negative Reinforcers. Loosely speaking, negative reinforcers are those unpleasant situations such as social disapproval or condemnation which the learner will readily terminate if given the opportunity to do so. When negative reinforcement is used, the response to be learned serves to terminate or eliminate the aversive stimulation. If engaging in homework is the only means by which a student can terminate the displeasure of a parent, the student may, over a period of time, learn to terminate this annoying stimulation quickly by engaging in the required tasks. Negative reinforcement, then, is a means of forcing behaviors to occur. Negative reinforcers are thought by many to be inefficient means of producing learning because they may force the occurrence of both wanted and unwanted behaviors. Moreover, unwanted emotional responses to an aversive situation may be difficult to subsequently modify.

Punishers. A punisher is an aversive stimulus which follows a response and frequently serves to suppress it. It is important to distinguish between negative reinforcers and punishers. Negative reinforcers precede the response and force its occurrence in order to terminate the unpleasant condition. In contrast, punishers follow the response and decrease the likelihood that the response will be made again. If disapproval or other annoying stimulation follows immediately after a behavior, punishment has taken place. On the other hand, when disapproval and scolding are directed at an individual in an effort to force behavior to occur and his behavior can terminate this condition, negative reinforcement is being used. Negative reinforcers and punishers are often grouped together under the term "aversive stimuli," since a given stimulus may often be used in both ways; the relationship to the response is the critical distinction between then.

Disapproval and condemnation given long after the occurrence of an incorrect behavior have little effect in weakening the behavior. Like all reinforcing stimuli, punishment is effective only when it is relatively immediate. However, even with immediate punishment, the behavior may not be permanently suppressed unless punishment continues to be maintained. The research on punishment does not yet clearly indicate whether punishment can be trusted to have long term behavioral effects except under special conditions.

In summary, some responses will be learned and others will not as a result of the effects which the responses produce. By definition, a positive reinforcer is a stimulus which when made contingent upon the occurrence of a response, serves to strengthen and perpetuate the response. Aversive stimuli may serve to suppress, but not always to eliminate, responses. Punishers and negative reinforcers can seldom be used by themselves to point the way to other, more desirable forms of behavior and if they are intense they may hinder the educational process by suppressing all but avoidance behavior within the educational setting.

Secondary Reinforcement

The properties of the various types of reinforcing stimuli tend to spread to other aspects of the learning environment in which they are used. Neutral stimuli which are accidently or deliberately associated with a reinforcer may acquire the ability to reinforce behavior by themselves. The pleasant effects of candy, for example, may spread to the store in which candy is obtained or to the person who dispenses the candy. The psychologist distinguishes between stimuli which seem to be naturally reinforcing, such as food, water, or pain, and those stimuli which acquire reinforcing properties through learning, such as money, praise or criticism. Reinforcing stimuli which seem to be naturally or innately reinforcing are referred to as primary reinforcers. Derived or learned reinforcers are technically called secondary reinforcers.

Just as the pleasant effects of a positive reinforcer may generalize to the environment, the effects of aversive stimuli may also generalize and suppress ongoing behaviors. When an individual is returned to an environment in which he was previously punished, nearly all his responses may be suppressed except those required in avoiding direct contact with the aversive stimuli. After considerable exposure to aversive stimulation such suppression of behavior may be brought about even by the suggestion that the learner return to the aversive environment. Thus, secondary reinforcers like primary reinforcers can be either positive or aversive.

Typically, secondary reinforcers are the only ones available in an educational situation. Teachers make use of praise, grades, criticism, promotion, and fear of failure in order to modify student behavior. Numerous studies have shown that another highly effective reinforcer is receiving knowledge of results, i.e., being told whether a response is correct immediately after responding. Knowledge of results or confirmation, as it is sometimes called, is particularly suitable for an instructional situation and is often assumed to be the major reinforcer in present techniques of programmed instruction.

Reinforcement in Education and in Programming

Positive reinforcement can facilitate instruction in that behaviors for which rewards are available will become behaviors in which a learner prefers to engage. Moreover, positive reinforcement often results in a general heightening in activity which may be useful for instructional purposes. Praise, encouragement, and success seem to promote continued interest and enthusiasm for the learning task and perhaps the entire educational situation. In contrast, teaching through aversive stimulation, by means of disapproval or fear of failure, may lead to generally negative attitudes and the learning situation itself may become something to be avoided.

Programmed learning is based on a philosophy which suggests the consistent use of positive reinforcement. In addition to knowledge of results, there are many other potentially useful reinforcers in programming depending upon the characteristics and general background of the students for whom the program is intended. For very young children, being able to turn a page in a book may be strongly reinforcing. The direction to turn the page and being able to do so, constitutes a reinforcing event. Finding a short cut or an easier way to emit a certain response is also reinforcing for most learners. In programming as well as instruction in general, clever use should be made of all such reinforcers. The often heard dictum that being right is the sole reinforcer is too limited: a program should use as many reinforcers as the programmer can think of. In the context of teaching machines, additional reinforcers might also be found in clever techniques of automation.

A distinction should be made between a reinforcer and what might be called a bonus. It is not enough to provide a generally pleasant and approving atmosphere for the learner. He must earn the reinforcer. If rewards are dispensed without reference to the student's accomplishment, there is no knowing what behaviors will be reinforced and hence learned. Whatever behavior is in process at the time a reinforcer is given will be affected by the reinforcer. Thus it is essential to make reinforcement contingent only upon desirable performance. Further, a reinforcement is not a bribe. A bribe is typically proffered before desired behavior has occurred. If the person to whom a bribe is offered happens to be stalling at the moment, the bribe may reinforce or strengthen stalling. The essence of a reinforcer is that it is produced by and is a consequence of the learner's behavior.

A program will almost always be used within a larger educational environment and the program's effectiveness can be maximized by an understanding of how reinforcement is used in the larger environment. The overall decision regarding whether a particular program should be used is subservient to more general considerations concerning the management of the total instructional situation. In the learner's environment, some of the most potent reinforcing stimuli are social in nature, i.e., derived from people. These social reinforcers are managed through the interpersonal relationship between the instructor and the student. However, the same principles of learning which give rise to efficient programs may be employed to make the interpersonal relationship more efficient and conducive to learning. When the instructor understands the proper way to use positive reinforcement and the way reinforcement affects behavior, he is in a position to make maximum use of a program and to carry out an important role in mediating social reinforcement.

Extinction

Extinction, or unlearning as it is sometimes called, refers to the process of omitting reinforcement and permitting a response to go unreinforced. When a response is no longer reinforced it will occur less and less frequently and eventually be "unlearned." For example, a person who inserts a nickel in a broken stamp machine and gets no stamp for his money, soon stops dropping nickels into the slot. Eliminating a response or a repertoire through extinction requires, first of all, identifying the reinforcers which are operating, since these are the agencies through which the response is maintained at some strength. Having identified the reinforcers, one is in a position to attempt to eliminate them so that the response involved will weaken and eventually extinguish.

The term extinction is used to refer to both the process and its effect. Extinction as an operation consists of removing or blocking the prevailing reinforcers. Extinction as a behavioral effect is the decrease in frequency or likelihood of a response. The term may also refer to the weakening of stimulus control over a response. The phenomenon of extinction is of great importance to learning theory, but its practical implications for programmed instruction are less obvious currently than those of reinforcement.

Extinction Contrasted to Admonition and Persuasion. Verbal admonition, explanation, and persuasion are frequently used in education as attempts to guide student behavior. Such attempts may be effective when they prompt desirable behavior which can then be reinforced. Explanation or exposition by itself, however, is neither a sufficient or necessary condition for the occurrence of learning. It is only when the learning environment makes the student respond actively to whatever materials are presented that the conditions for effective learning are approximated. On the other hand, if admonition and persuasion are used as negative reinforcers which the student will seek to avoid, they have little value in instruction. Generally speaking, a more reliable way of removing learned responses is to identify those aspects of the environment which reinforce the unwanted behavior and to arrange the environment so as to prevent these reinforcers from occurring.

Extinction Contrasted to Punishment. In the process of extinction, reinforcement is withheld with a consequent drop in response likelihood. In contrast, when a response is punished, a noxious consequence is produced by the undesirable behavior. It should be obvious that punishment and extinction involve very different operations and result in different behavioral effects. Consider the differences between the student whose behavior is met with a verbal reprimand (punishment) and one whose behavior is completely ignored (extinction). Reprimands and physical punishment often immediately suppress the punished response, but this suppression may be specific only to the immediate environment and may not be permanent. On the other hand, if an individual's behavior has not been reinforced over a series of occasions, it is unlikely that the behavior will occur. Thus a student's misconduct in a classroom may be extinguished if he is ignored by everyone in the room. Punishment might temporarily stop him from misbehaving, but the attention he receives while being punished might serve to reinforce his misbehavior.

Extinction and Response Substitution in Programmed Learning. In a learning program, the extinction process (i.e., the deliberate withholding of reinforcement) is seldom used as a separate procedure. The student is rarely if ever encouraged to engage in behavior which is left unconfirmed. If the student responds incorrectly to subject matter stimuli, one way to eliminate the incorrect response, of course, would be to withhold reinforcement. A more useful procedure with human behavior, however, is to teach a competing, desirable response to the stimulus. For example, most students begin algebra with considerable past learning in the use of letters of the alphabet. When asked what "x" is, the average student will answer that it is a letter of the alphabet; but in algebra the student must learn that x stands for an unknown quantity. Since the old response is desirable in other contexts, the algebra teacher or the algebra program will attach the additional response, "an unknown quantity," to the letter x rather than extinguishing the old response. This process is called response substitution and it appears to have much more practical relevance to programmed learning than does extinction as such.

Spontaneous Recovery and Warm-Up

Two phenomena which have been relatively well investigated in psychology and are only occasionally referred to in programming literature, are spontaneous recovery and warm-up. The recurrence of an extinguished response is called spontaneous recovery. Following the extinction of a response the learner may again be placed in the extinction situation and, if some time has passed since the first extinction session, a sudden recurrence of responding is generally noted. The name of the phenomenon is somewhat misleading since spontaneous recovery is often predictable and often anything but spontaneous. The second phenomenon, warm-up, has been observed in studies of industrial productivity and human skill-learning. It refers to the frequent situation in which a person with learned skills performs in a relatively poor fashion at the beginning of a work session and improves in performance as the session proceeds.

While spontaneous recovery and warm-up are not explicitly incorporated in programming, the reliability with which these phenomena occur should be taken into account both in the administration of programs and in the management of the total learning environment. The programmer or instructor may easily succeed in substituting a new response to an old and familiar stimulus, but he should be prepared to find a student giving the incorrect response at some future time. Such an intrusion is similar to the spontaneous recovery of an old response. In any event, it is best to anticipate the possibility of intrusions in recently substituted responses by arranging appropriate review and practice sequences. Both extinction and response substitution are seldom complete in a single learning session and some amount of time, even if only a few hours, should probably be allowed to elapse between original learning and subsequent review. The same considerations apply in the classroom where the instructor may successfully extinguish behavior only to find it returning again at the next class meeting.

Both spontaneous recovery and warm-up increase with the amount of time the learner spends out of the situation. The longer it has been since extinction or substitution took place, the greater the amount of spontaneous recovery to be expected. Similarly, the longer a skilled operator has been out of his operating situation the longer the time necessary to achieve

maximum performance and hence the greater the amount of time required for warm-up. Basing a prediction on various studies of learning, it seems likely that the number of frames covered per minute by a student in a program will increase from the beginning of a session to a peak somewhere in the middle of the session, assuming the frames to be of equal difficulty. It also seems likely that the amount of time required for warm-up will decrease as the similarity of the materials covered in consecutive sessions increases. While traditional educational practice has been to terminate subject matter sub-units at the end of a class meeting, somewhat the opposite practice may be indicated by what is known of the warm-up phenomenon. It may be that the transition between sub-topics or units of the subject matter should occur in the middle of a session rather than between sessions, if the highest rate of progress is to be achieved throughout the entire program.

The foregoing predictions regarding spontaneous recovery and warm-up are not the results of experimental studies with programmed learning materials. The appropriate research on such questions remains to be done. However, these speculations do point out that traditional practices may be changed as a result of considering the conditions necessary for learning.

Summary

Major concepts and operations in the management of behavior were identified in this chapter. The principles discussed are relevant to the instructional setting as a whole as well as to specific instructional techniques such as programming. Some of the important points covered in this chapter are:

1. To the scientist and instructor, behavior refers to the overt, observable, and measurable aspects of an individual's actions. Learning involves the modification of behavior. The instructor's goal is to modify student behavior with respect to subject matter stimuli.

2. A stimulus is that aspect of an individual's environment that is responsible for producing a given behavior. The number of stimuli that control behavior increases with age, through learning.

3. A repertoire is a group of responses which bear some logical or functional relationship to one another. An individual's total behavior consists of many repertoires. While any number of repertoires can be identified depending on the subject matter, some repertoires of general importance are: discriminative, serial, self-sustained, continuous, discrete, verbal and interverbal repertoires. A student's entrance repertoire is comprised of whatever behaviors he brings to the instructional situation. The terminal repertoire consists of the behavior which the student should acquire from the instructional process.

4. The consequences of an organism's actions are critical in both the modification and maintenance of behavior. The occurrence of consequences of behavior that are effective in producing and maintaining behavior is called reinforcement. The term reinforcement refers to the process of providing such effective behavioral consequences.

5. Reinforcers are the stimuli produced by the learner's response. These stimuli may be positive reinforcers, negative reinforcers, or punishers. Positive reinforcers include reinforcing stimuli which the organism seeks or obtains by his actions. Negative reinforcers are those stimuli which the organism's response serves to eliminate. In contrast, punishers follow the response and subsequently suppress its occurrence to the particular stimulus.

6. Reinforcers are effective in modifying behavior because they themselves elicit a response from the learner. The strength of this response is a possible measure of the reinforcer's power to reinforce. A reinforcer's strength may exist naturally or may be acquired by learning.

7. The effect of a reinforcer depends on its immediacy in following the behavior it is to reinforce. With delays in reinforcement, learning may not take place, or undesired responses may be reinforced and learned.

8. Extinction is the process of omitting reinforcement and permitting a response to be unreinforced. In this way, a given response to a stimulus is unlearned or decreases in frequency. For instructional purposes, however, response substitution seems to be a more relevant procedure than extinction alone. In the process of response substitution, a new and competing response is taught to a particular stimulus.

9. Spontaneous recovery and warm-up are two phenomena which the instructor may observe occasionally. Both the recovery of extinguished behavior and the warm-up of skilled behavior should be given consideration in those instructional situations in which they may occur.

10. In the training situation, the instructor attempts to: a) bring new stimuli to control the learner's behavior, b) guide the learner's response to subject matter stimuli, and c) arrange for reinforcing consequences of behavior. In order to maximize positive reinforcement while the student gains mastery, it may be necessary to tolerate approximations of the desired response and as learning proceeds require increasingly closer approximations to the terminal behavior.

11. In general, programmed instruction is based on a philosophy of consistent, positive reinforcement, but the effectiveness of programming or any other teaching method is dependent upon the instructional environment in which it is used. For the most part, the reinforcers available to the instructor are learned or secondary. Some learned positive reinforcers which may be especially useful in instruction are confirmation of a response, praise, and being allowed to proceed to another response.

Chapter 3: Stimulus Control of Behavior

The behavior of an expert in a given subject matter is characterized by its quality, flexibility, and appropriateness, as well as the facility with which it is called out by particular subject matter contexts. Moreover, the expert's behavior is apparently self-sustaining; the expert may continue to respond for relatively long periods of time without the stimulus support from references or books that is needed by a learner. Put another way, the expert's behavior is made up of numerous self-sustaining discriminative repertoires--he can make a great number of precise responses to many subject matter stimuli.

Any course of instruction is an arrangement for a student to acquire the numerous discriminative responses that characterize expertise or "knowledge" in that subject matter; the student must come to display appropriate behaviors to the subject matter environment. Another way of saying this is that his responses must come to be controlled by the subject matter. As Chapter 2 indicated, a given response is caused or elicited by a particular stimulus. The phrase, stimulus control of behavior, refers to this fact. The present chapter is concerned with the operations which establish stimulus control over behavior. By means of these operations, neutral or previously ineffective stimuli are brought to set the occasion for specified behavior. This manipulation or stimulus control of behavior is basic to instructional efforts.

Discriminative Behavior

That particular stimuli should come to call out particular responses is an assumption of nearly all training procedures. When a stimulus, through conditions of learning, comes to set the occasion for a response it is called a control or controlling stimulus. In the sense that the learner must be able to identify such stimuli from the general environmental background in order to respond, it may be said that a control stimulus is a discriminative stimulus, i.e., one which the learner must come to discriminate from other stimuli. The process by which subject

matter or environmental stimuli in general are brought to control behavior is typically called discrimination training.[1]

The phrase "three-term contingency" can be used to describe the relationship of factors which combine in discrimination learning. The three terms or events involved in the establishment of a new discriminative response are (a) a stimulus for the response, (b) the response itself, and (c) the appropriate reinforcement for the response. The use of the word "contingency" indicates that each term or event is dependent upon the preceding term. The capital letter S is usually used as an abbreviation for the stimulus. When a stimulus is deliberately used in a discrimination training situation the letters S^D are used to stand for discriminative stimulus. The S^D is the stimulus to which the organism's response becomes attached through appropriate arrangement of the conditions which lead to reinforcement. A discriminative stimulus comes to set the occasion for a particular response because the response is reinforced only in the presence of that stimulus. A response is designated by the symbol R. The discriminative stimulus and its appropriate response are thus the first two of the three terms in the three-term contingency. The final term is, of course, the reinforcing stimulus symbolized by S^R.

When the three terms are assembled in their order of occurrence in time they look like this: $S^D \quad R \quad S^R$. First, the stimulus for the response must occur; it may occur naturally in the environment of the individual or it may be deliberately contrived. Second, the appropriate response (R) must occur to the S^D and then must be immediately reinforced (S^R). The following is a simple example of a three-term contingency. In the cockpit of an airplane the warning light flashes on (S^D) indicating that one fuel tank is nearly empty and that a new tank must be called into service. The pilot responds (R) by throwing a switch which cuts the reserve tank into service. The pilot is reinforced--his behavior in this situation is maintained--by the termination of the warning light and the continuation

---

[1] In the following discussion the terms "discriminative stimulus" and "control stimulus" will be used interchangeably.

of the flight (S^R). The three-term contingency is a useful explanatory model, but its simplicity should not detract from the complexity of human behavior, just as the statement of a principle of physics in simplified terms does not make the natural phenomena around us any less complex.

The precision or accuracy of the responses in the discriminative repertoire indicates the degree to which behavior is appropriate in a particular stimulus context; correct responses to arithmetic stimuli, for example, are obviously the most appropriate responses to the stimuli. Discriminative behavior is increased in precision by means of certain operations that vary the specific conditions leading to reinforcement. These operations are simple, but result in a great complexity of behavior.

The following pages describe operations involved in the acquisition of discriminative behavior. For the programmer it must be re-emphasized that these are the principles or operations which appear to underlie the way in which subject matter materials and on-the-job stimuli influence and control trainee performance. The skill with which the programmer is able to apply such principles will in large measure determine the effectiveness of his program and the nature of his recommendations for integrating the program into a total curriculum. To a great extent these principles and practices are extrapolations from basic research and theory in learning and require further research and development to establish their reliability. However, practical work with such extrapolations should facilitate the development of both instructional practices and research endeavors in the scientific study of behavior.

Establishment of Stimulus Control

To establish the stimulus control of a response (i.e., to arrange for the response to occur in the presence of a particular stimulus), the response must be reinforced when the stimulus is present. Reinforcement will serve to keep the response at high strength whenever these stimulus conditions exist. As previously indicated, S^D is the occasion upon which the response is appropriate and should be reinforced. All other situations are designated as S^{Δ} (s-delta) situations. S^{Δ} is any other stimulus situation which should not be the occasion for the given response.

S^{Δ} might be a stimulus which evokes no behavior at all or evokes some different, competing, or substitute response. Since there are few subject matter stimuli which should occasion no behavior at all, what is S^D in one situation may very well be S^{Δ} in another. S^D, then, is defined by the training conditions of the moment; it is that stimulus to which a response is being trained. All other stimuli are S^{Δ} stimuli unless they are explicitly used as S^D's in training.

In discrimination training, the correct response to S^D is reinforced in the presence of S^D, but extinguished in the presence of all S^{Δ}'s by withholding any kind of reinforcement. Thus every correct response made during periods when the S^D is present, is reinforced. Responses made when the S^D is not present (i.e., during an S^{Δ} situation) are not reinforced. Within the educational setting it is more efficient to prompt the desired response to S^D than to wait for it to occur. This method might be used, for example, in aircraft identification training. In the presence of a picture of an B-52, the correct response would be prompted initially by the written or spoken statement, "This is an B-52." Under these conditions the correct response would be almost certain to occur and could be reinforced. Other types of aircraft should then be presented and any responses made to them extinguished by ignoring them. This is an obviously artificial training situation since training would involve identifying all types of aircraft, not just one.

A variation of discrimination training is of greater practicality in instruction because it results in several discriminations being trained simultaneously. To illustrate, an experimenter training a rat might arrange three colored lights--red, green and blue--in the rat's box. Pressing a lever could be reinforced in the presence of the red light, a running response could be reinforced in the presence of the green light, and a string-pulling response reinforced in the presence of the blue light. This simultaneous conditioning method of establishing discriminations is a process often used in instruction. The individual learning to identify types of aircraft learns all types more or less simultaneously.

At first the correct response to each picture is prompted, then (in programmed training) the prompts are gradually withdrawn leaving the responses attached to the pictures alone.

In summary, gaining stimulus control over behavior involves (a) training on single discrimination with reinforcement of S^D behavior and extinction of S^Δ behavior, or (b) simultaneous conditioning of different responses to different S^D's. The generalized discrimination training method can be diagrammed as follows:

$$S^D \longrightarrow R \longrightarrow S^R$$

$$S^\Delta \dashrightarrow R \longrightarrow \text{Extinction}$$

Simultaneous training can be diagrammed as:

$$S_1^D \longrightarrow R_1 \longrightarrow S^R$$

$$S_2^D \longrightarrow R_2 \longrightarrow S^R$$

$$S_3^D \longrightarrow R_3 \longrightarrow S^R$$

$$S_n^D \longrightarrow R_n \longrightarrow S^R$$

where 1, 2, 3 ... n refer to the different stimulus response combinations being established.

It should be noted that the process of extinction also operates during training in the multiple-stimulus, multiple-response situation. In learning different types of aircraft, a picture of an B-52 is a S^D for the response "B-52" but is also an S^Δ (non-reinforcement situation) for any other response such as "F-102" or "C-130." A picture of an F-102 is an S^Δ for any response except "F-102." Thus, in both training situations any incorrect responses are extinguished. It should also be obvious that when <u>no</u> aircraft pictures are being shown to the student he is in an S^Δ condition and will not be reinforced for naming aircraft at all.

In the preceding example, the separate responses to the different aircraft comprise a discriminative repertoire which is under the control of the aircraft pictures used in the training situation. Subject matter stimuli can not come to control behavior unless there is an opportunity for extinction to occur to S^{Δ} stimuli or unless competing responses are deliberately established to the multiple stimuli. When a particular behavior is always reinforced in one situation, but never in others, the learner will form discriminations more or less gradually over a series of practice trials. This process is very different from simply telling the learner to notice that a certain subject matter stimulus should make him behave in such and such a way. The active participation of the learner is a necessary part of the three-term contingency.

Sharpening of Control

The preceding section indicated how a response may be strengthened in special stimulus situations by means of reinforcement, and weakened on alternate occasions through extinction or simultaneous conditioning. The control of a response by a particular stimulus may be further sharpened by presenting stimuli similar to the one which should evoke the response. By extinguishing the response to similar but slightly different stimuli and continuing to reinforce responses to the S^D, it is possible to train an individual to make increasingly more precise discriminations.

The tendency for stimuli similar to the S^D to also call out the response to the S^D is a well-known fact of behavior called stimulus generalization. Often the learner's tendency to generalize the effects of training in one stimulus situation to other similar situations is a desirable end-product of training. On the other hand, if such stimulus generalization leads to errors, further sharpening of the discrimination is indicated. This might be done by presenting similar but S^{Δ} stimuli and either permitting the student to learn different responses to them or extinguishing incorrect responses to them. The foregoing may sound very much like any standard training situation, but the reader should remember that the attempt is being made to describe training using a systematic technical vocabulary.

Extension or Expansion of Control

The discussion thus far has been concerned with the means for bringing a response under the control of only one stimulus. In human verbal behavior, however, there are many cases in which two or more stimuli, often stimuli of a very different nature, must come to call out the same response. Words, for example, come to stand for concrete objects and to set the occasion for many of the same responses produced by the objects themselves. Such "substitution learning" occurs because once a response is reliably evoked in the presence of a particular stimulus, a second stimulus may be brought to control the response by presenting the two stimuli together. Thus the ability of one stimulus to call out a particular response may be extended to other dissimilar stimuli if the two stimuli are closely associated in time and space. The extension of the behavioral properties of one stimulus to another stimulus with which it is associated is a well-known phenomenon. Situations in which pleasant activities take place themselves become pleasant. Similarly, the effect of unpleasant activity is often to make the situation one to be avoided just as the activity itself is avoided.

Most children who have learned to read can look at the word "zebra" for the first time and read it aloud with approximately the correct pronunciation. A child can do this without knowing anything about the object to which the word refers. If a picture or photograph of the animal appears together with the written label, the child may immediately associate the label with the picture of the animal. Very little training is needed to establish either the correct reading of the word or the association between the word and the object. The instructor's task is to arrange a learning sequence in which the child will become able to name the animal without the support of the verbal label.

In most cases the verbal response can be gradually extended to the picture or object over a series of trials or, in a program, over a series of frames. An extremely useful technique in extending stimulus control is "fading." Fading, in the example above, is the gradual elimination of the written label so that the learner is forced increasingly to depend upon the picture itself as a cue for the name, "zebra." Although the written label permits the student initially to respond correctly to the

novel stimulus (the picture), the programmer must eliminate dependence upon the label while also maintaining the correct response. Extension of control is very often the crux of a programmed instructional sequence. It is, in fact, the reason that prompts or cues can be useful. A prompt sets the occasion for correct behavior in the presence of to-be-learned stimuli; the extension of control cannot be considered complete until the prompt has been successfully removed.

A related situation involves the apparent association of several responses with one stimulus. Thus the meanings of words in everyday language may be quite inappropriate in particular technical contexts. In biology, for example, the term "extinction" refers to the disappearance of a species of animal. The reader is familiar with the very different use of "extinction" in psychology. In changing from the context of one discipline to the other, the S^D which comes to control the response to the word "extinction" is the use of the word in a particular subject matter situation. Response substitution is the process by which new responses are attached to a familiar stimulus under certain stimulus conditions. The substitution of responses is an essential procedure whenever students come to a learning situation with incorrect behavior already attached to elements of the subject matter.

Consolidation of Control

A particular verbal response can refer to an entire class of stimuli as, for example, when a group of dissimilar organisms are all classified as animals. In education, it is frequently desirable to combine independently strengthened discriminative responses under the control of a single stimulus condition. Thus the separate responses "bear," "dog," "horse," and "chicken" would all be placed under the control of the more general stimulus, "animal." This process is often called teaching a rule--it illustrates the consolidation of discriminative control. Consider the statement, "All of the plaster models in this case are models of mammals, point out what is it about each that makes it a mammal." A similar statement might be, "Let's speak Spanish now, pronounce the vowels as they are pronounced in Spanish." The use of the words "mammals" and "Spanish" assumes that these words control certain discriminate repertoires.

A large part of what we call understanding of a subject matter appears to consist of precise discriminative repertoires which have themselves come under the control of appropriate more general stimuli, such as a concept or a rule.

The consolidation of control is a means of assuring that competing repertoires do not interfere with each other and that behavior has the degree of flexibility necessary in a changing environment. The mere mention of the word "mammals" to a biology student immediately increases the probability of a large group of responses. The suggestion that the class is going to discuss a group of animals called mammals raises an appropriate discriminative repertoire to high strength, while many other responses which could be appropriate in biology classes are weakened. In other words, the students are ready to discuss mammals, not insects or fish. Since the understanding of a rule is a frequent goal in education and training, it would seem worthwhile for a programmer or an instructor to provide training in the appropriate use of different rules. This can be done by alternating between instructional segments which call for the use of different rules--as between the way the vowels are said in English and Spanish--so that the student has an opportunity to discriminate his own behavior in different circumstances.

All the processes of establishing and modifying stimulus control which have been presented employ only two fundamental operations: reinforcement and non-reinforcement. The operations described for manipulating stimulus control illustrate some general classes of learning situations. From the strict point of view of learning theory, the notions discussed may be both incomplete and overlapping. From the programmer's point of view it may be difficult to keep all of the methods for manipulating stimulus control in mind while also concentrating on subject matter and its arrangement into frames. However, the programmer who is familiar with the principles of discrimination learning will find that his programming technique has a degree of flexibility and adaptability that is difficult to acquire in ignorance of basic principles of learning.

Discrimination and Differentiation

Thus far the discussion has centered on external stimuli in the presence of which a response is emitted. In a similar manner, however, responses may in some instances be elicited by feedback from preceding responses, rather than by stimuli in the external environment. Skillful responses, such as working a lathe or pitching a ball, involve a sequence of internally controlled movements in which, presumably, each response made serves as the stimulus for the next response. In the course of learning such skillful behaviors, an individual's responses become increasingly more precise as training proceeds. The learning process whereby these behaviors increase in precision is called differentiation and a skillful response itself is called a differentiated response. For differentiated responses, sensory stimuli from the muscles, tendons, and skeletal joints control further muscular movements. In general, the learning of motor skills, as opposed to perceptual skills, involves the process of response differentiation.

In differentiation training it is primarily the <u>way</u> in which the differentiated response is executed--the specific form of the response--that determines whether reinforcement is given or withheld. However, when the terminal repertoire is a finely differentiated response that is highly specific and precise, the probability of <u>incorrect</u> responses being emitted during training is so great that all behavior may eventually be extinguished if careful approximations to the terminal behavior are not used. The notion of permissible error tolerances, mentioned in Chapter 2, is of great utility in approximating a skilled response. For early approximations of a motor skill, error tolerances must be quite broad so that reinforcement is frequent. As performance becomes coincident with one range of error tolerances, tolerances should be contracted slightly to produce a further improvement in performance. Thus differentiations, like discriminations, can be programmed and taught in gradual stages through approximations (although much less work has been performed on programming motor skills than has been carried out for verbal responses).

Examples of differentiated behaviors include: learning to aim a rifle to hit the bull's eye, learning to pronounce a letter so that the sound is similar to that acceptable in the verbal community, and learning to bowl with accuracy. In contrast, some skills that primarily involve discrimination are: learning to read printed words, learning to use a slide rule, and simply learning to tell the difference between a circle and a square. Many activities include discriminations of external situations and differentiations of precise muscular movements as well, e.g., playing a musical instrument, dancing, and writing in longhand.

Since the stimuli which facilitate the occurrence and reinforcement of a differentiated response arise from the response itself, it is very nearly impossible, with present techniques, to determine the specific nature of these internally produced stimuli. As a result, the instructor has no direct control of the stimuli that produce a sequence of skilled muscular movements. However, he can make the desired response more probable by means of verbal directions and other environmental arrangements that heighten the likelihood of correct performance. A harness might be used in teaching good diving form, for example. Good bowling shoes could be provided a beginning bowler to prevent slipping. More than simply arranging the environment to maximize performance, the teacher should take the notion of approximations seriously. The boy learning to pitch a baseball should be expected to throw it only half the standard distance initially, and the beginning bowler might be started out on a short alley. As proficiency increases, the distances (error tolerances, in a sense) should be gradually increased to standard conditions.

Frequently, the process of differentiating the form of a response can be speeded up by first teaching the student to discriminate the desired form of the response in others. It is often easier to learn to perform a specific skilled act if the learner knows what the act should look like or sound like. It would seem difficult, for example, to learn to play the piano well without ever having heard good pianists; certainly it would seem to require a longer period of training. In general, when discrimination of the correct form of behavior precedes differentiation of that behavior, training time may be saved.

Most current efforts in programmed learning involve discrimination training using verbal or symbolic subject matter stimuli. Such verbal programming is the primary concern of this book. However, the distinction between discrimination and differentiation is important because it calls attention to the learner's response. It has been pointed out that in verbal programming the programmer may start with very rough discriminations of different terms, principles and rules. These discriminations become increasingly finer and of greater number as the program progresses. In addition to the elaboration of discriminations, however, the program must lead the student to larger and larger segments of behavior which are relatively free of external prompting. Even the verbal symbolic program, then, is usually best designed when it differentiates, or leads to the production of, increasingly complex and self-sustained behavior. Some programs which are not designed to produce the highest levels of ability in the student may never require more than a one or two word response. However, a program that claims to teach mastery of a subject should generally call for larger and complete statements from the student as training proceeds.

In summary, discrimination training directs attention to the stimuli in the learning situation. Discriminations may be approximated by gradually reducing the differences between the stimuli to be discriminated while the total number of stimuli and associated responses are increased. Differentiation training, on the other hand, calls attention to the form or features of the behavior itself. Differentiations may be approximated by gradually requiring more and more precise responses. Approximations of both discriminations and differentiations involve a slow reduction of the variation in acceptable behavior. Optimally, both discrimination and differentiation training depend upon selective reinforcement, extinction of incorrect performances, successive approximations, and a high frequency of reinforcement for correct responses.

Stimulus Generalization

When a response to a particular stimulus is reinforced the likelihood is increased that the response will also occur to similar stimuli. The tendency of similar, but not identical stimuli to elicit learned behavior is called stimulus generalization. Students who have learned about a simple one-cylinder internal combustion engine are very likely to call any other engine that operates by combustion of compressed vapors an internal combustion engine regardless of the type of fuel used, the number of cylinders or the use of the engine. Although this example illustrates highly complex behavior, it is similar to the simpler phenomena found under laboratory conditions. Generalization can be obtained by establishing a response to a specific stimulus through training and subsequently eliciting the same or a similar response after slight changes have been made in the control stimulus. The greater the change in the stimulus, the less likely it is that the learner will emit the response. Conversely, the more similar the stimuli among which the learner must discriminate the more likely it is that he will confuse the stimuli and, therefore, the more precise and deliberate must be a discrimination training procedure.

Often the stimuli in the learner's environment are highly complex and consist of intricate stimulus patterns. The term "abstraction" is frequently applied to discriminative behavior which has come under the control of a set of complex stimuli. For example, the term "animals" is an abstraction made in response to a class of stimuli, in which responses to the specific elements of the complex stimulus (the characteristics of organisms) have been generalized over a variety of different species. In beginning biology the student is taught to see similarities between one-celled animals and man; e.g., both man and amoeba convert types of energy, excrete, reproduce, move about, and cannot live without certain substances. Each of these common characteristics is in itself an abstraction. Even though the stimuli involved are extremely divergent, such as men and one-celled animals, the competent student of biology emits certain common responses to all objects in the stimulus class called animals.

If the commonality of his behavior to diverse objects is not pointed out to the student, it may be a long time before he himself makes the induction. Induction from particular instances to general principles is the method by which scientists form abstractions, but may be too difficult a process for the student. Moreover, it is probably wasteful to force the student to rediscover all the abstractions of a subject matter. Instead, the commonality of established behavior may be pointed out to him and presented as a discriminative stimulus. Following training, the advanced student must be able to discriminate the properties of his own behavior to newly observed stimuli so that he can transfer his abstraction and extend it in order to form inductions and generalizations on his own.

Stimulus generalization is not always a desirable product of training. Often the learner will generalize his responses to incorrect stimuli. Learners may either over-generalize or under-generalize, and if they are left to their own devices there is no assurance that they will respond appropriately to a new class of stimuli. Implicit in the preceding sections on discriminative control is the notion that the trainee should not be left unguided, at least during the early and middle stages of training.

If the learning environment is not carefully controlled, it is likely that incorrect generalizations will be reinforced. Programmed instruction offers an opportunity to inspect and test subject materials prior to teaching so that the extent and amount of discrimination and generalization training may be controlled. A sequence of frames designed to teach generalization, for example, can be tried out on subjects to determine its effectiveness. Careful evaluations of student performance as a result of the learning program permit objective conclusions about whether a program or sequence achieves its goal of generalization; and if it does not, the program can be rewritten appropriately and retested prior to publication.

If generalization or the absence of it is a critical goal of training, a learning program should include appropriate sequences of frames to insure the precision of the resulting discriminations or the breadth of subsequent generalizations. Such general principles as the sharpening and extension of control are relevant in this connection and may be translated into specific programming procedures such as those outlined in Chapters 5 and 6.

Response Chaining and the Integration of Behavior

A chain of responses is a sequence of responses emitted by an organism in which each member of the chain appears to have discriminative properties (acts as an S^D) for the subsequent members. Thus a response in a chain is both a response to the preceding stimulus and a discriminative stimulus for the next response. The final result of a chain of behaviors is the reinforcing event or state at the termination of the chain--it is the reason why the chain exists at all in the organism's repertoire. Because of this, a chain of behaviors which culminates in reinforcement is referred to as a functional unit.

Many of the expert's behaviors illustrate the principle of chaining. Expert behaviors are performed in a smoothly flowing sequence. The technical vocabulary of an expert does not consist of single responses, but of elements in chains of responses. The expert in neurophysiology may use such words as hypothalamus, pituitary, anterior, and follicle-stimulating hormone. He is considered an expert, however, only when he combines these and other terms into meaningful statements such as, "a follicle-stimulating hormone which stimulates the growth of spermatogenic tissue, appears to be secreted by the anterior pituitary." This statement is an example of a chain of verbal behaviors.

In essence then, the terminal behavior desired of a student in a given subject matter is the ability to perform a chain or chains of behavior. Throughout their schooling, students acquire many chains of verbal behavior from reciting the alphabet or counting to multiplication tables, poems, stories, or chemical formulas. Such chains are usually taught by starting with the first element or first few elements of the chain and moving gradually towards the end of the chain. For example, children are taught the alphabet in the order A, B, C, D, E. It is common practice in much experimental work with animals, however, to teach a chain of behaviors by beginning at the end of the chain. In the laboratory, training in a chain of behaviors usually begins with the last-to-occur member of the chain and proceeds in a backwards fashion towards the first-to-occur member of the chain. That is, the order in which the chain is taught and the order in which it is performed are opposite. The reason for this procedure is that

the terminal member of the chain is the response which eventuates in reinforcement or which is instrumental in producing the reinforcer.

A simple chain of behaviors in the rat such as pulling a loop of string, followed by pressing a lever and then eating from a food magazine, has often been used in demonstrations of chaining. In this situation, the rat is first conditioned to eat from a food magazine which makes a click or some other sound. The effects of the food generalize to the sound of the magazine and the sound becomes a secondary reinforcer as well as a cue for the presence of food in the magazine.

After the rat has learned to approach and eat from the food magazine, the sound of the magazine is used to reinforce the lever-pressing response. When the rat presses the lever, the food magazine click is presented immediately, reinforcing lever pressing and signalling the presence of food. Thus the magazine click is also a discriminative stimulus for a response of moving away from the lever and towards the food magazine. The general procedure for chaining with animals requires that each member of a response chain be placed under discriminative control while it is established, just as the approach to the magazine was placed under the discriminative control of the click. The lever-press response is generally placed under the control of some external stimulus such as a light. When the light comes on, any lever presses made will be reinforced with the click.

After discriminative control of the lever press has been established so that the light reliably occasions a response, the third member of the chain (pulling a loop) may be established. Because the response to the light ultimately culminates in primary reinforcement, the light, like the food magazine click, acquires some reinforcing properties. Thus when a response to the loop occurs, the light is turned on, reinforcing the loop-pull and also setting the occasion for the lever-press response. The loop-pulling response may in turn be placed under discriminative control so that a buzzer, for example, signals the occasion for the loop-pulling response. At the sound of the buzzer, the loop-pulling response occurs resulting in the light being turned on, after which the lever press occurs, and so forth through the remainder of the chain.

The Process of Response Chaining

Reinforcing stimuli are also discriminative stimuli which lead to a response. As Chapter 2 indicated, one defining property of a reinforcing stimulus is the strong and consistent response it evokes from the learner. Generally, the more basic or "primary" the reinforcer, the more noticeable is the existing response to it. Thus a hungry dog exhibits strong and stereotyped behavior (eating) as a response to the reinforcer, food. This eating response, of course, continues to occur in addition to whatever response is being taught using the food as a reinforcer. A child's response to praise when praise is used to reinforce other behaviors may be less noticeable and a good deal more variable than the dog's response. Nevertheless, praise and other sorts of social reinforcement generally evoke at least a mild response, such as smiling or glancing up at the person who gives the reinforcement. The foregoing examples illustrate the discriminative properties of a reinforcing stimulus. This discriminative aspect of reinforcers permits the establishment and maintenance of chains of behavior.

In chaining, stimuli are used both to reinforce the preceding response as it occurs and to set the occasion for the subsequent response. In the chain of behaviors just described, the click of the food magazine reinforces lever pressing because the click has been associated with or led to food in the past. The click also becomes the S^D for approaching the food magazine. Similarly, the light is used to reinforce loop pulling and to set the occasion for the lever press. Symbolically, the responses involved look like this:

$$\overset{\text{Buzzer}}{\begin{bmatrix} \\ S_4^D \\ \\ \end{bmatrix}} \dashrightarrow \underset{\substack{\uparrow \\ \text{loop} \\ \text{pull}}}{R_4} \longrightarrow \overset{\text{Light}}{\begin{bmatrix} S_3^D \\ \\ S_3^R \end{bmatrix}} \dashrightarrow \underset{\substack{\uparrow \\ \text{lever} \\ \text{press}}}{R_3} \longrightarrow \overset{\text{Click}}{\begin{bmatrix} S_2^D \\ \\ S_2^R \end{bmatrix}} \dashrightarrow \underset{\substack{\uparrow \\ \text{approaching} \\ \text{food}}}{R_2} \longrightarrow \overset{\text{Food}}{\begin{bmatrix} S_1^D \\ \\ S_1^R \end{bmatrix}} \dashrightarrow \underset{\substack{\uparrow \\ \text{eating}}}{R_1}$$

R_1 is the eating response to food, R_2 is the approach to food, R_3 is the lever press, R_4 is the loop pull. Actually, many other behaviors at various levels of specificity are involved. Each chewing movement might, for example, be treated as a separate response and certainly the reader may wonder why the response of approaching the lever is not included. The diagram is intended only to symbolize the chain, however.

The parenthetical terms in the diagram indicate the external stimuli: (1) sight or smell of food, (2) magazine click, (3) light, and (4) buzzer. The buzzer, S_4^D only sets the occasion for the loop pull and is not used to reinforce any previous behavior. The stimuli are labeled with the two sets of symbols, S^D and S^R, to stress their dual function as reinforcers as well as discriminative stimuli. The reinforcing value of all the stimuli in the rat's situation, with the possible exception of food itself, is obviously learned during the training process. These learned reinforcers were originally neutral stimuli which acquired their reinforcing properties through association with the primary reinforcer--food.

Returning to the diagram of the chained sequence, the numbers refer to the order in which the response and associated discriminative stimuli were established or taught. The arrows, on the other hand, indicate the temporal direction or flow of behaviors when the chain is performed. The order in which behaviors were taught to the animal and the order in which the final chain occurs are exactly opposite.

Having trained an animal in this particular performance sequence, the trainer may expect that the entire chain will occur as frequently as the buzzer (the initial S^D) is turned on. The occurrence of the sequence is thus under the control of the trainer. The light for the lever press and the click for the food response are also external stimuli that cue the rat's dependence upon these external events by additional training. If the light and the click are eliminated abruptly the animal may take an increased amount of time to complete the chain. This effect may be only temporary, but in very long performance chains the disruption of behavior may so delay the final reinforcement that extinction takes place. If the intensity of the light and the click are diminished gradually over a series of trials, however, performance may be maintained at a high rate while it is made independent of environmental cues. At the completion of the final stage of training the rat's performance could be diagrammed as follows:

$$(S_4^D) \longrightarrow R_4 \longrightarrow R_3 \longrightarrow R_2 \longrightarrow \begin{bmatrix} S_1^D \\ S_1^R \end{bmatrix} \longrightarrow R_1$$

The initiating control (buzzer) and the sight and smell of food (S_1^D, S_1^R) remain, but the light and the click have been eliminated. The rat's own behavior has taken over the role of the removed stimuli so that pulling the loop has become the stimulus for pressing the bar. Similarly, a lever press has become the stimulus for approaching food. In short, it is possible to make the learner's behavior itself both reinforcing and discriminative. In terms of this particular chain of behavior, the rat has become a self-sufficient expert. He can now reel off complex behavior in a smooth sequence and without environmental crutches, thus displaying the characteristics of expert behavior.

Experimental versus Educational Techniques for Building Response Chains

It is essential to distinguish between the order in which responses in a chain are best learned and the order in which they occur after learning. These orders may be exactly opposite. Since it is rare for anyone to recite the alphabet in any way other than from A through Z, the alphabet is not usually taught in any other order. However, a simple

analysis of the laboratory rat's terminal behavior in performing the chain of responses might suggest a training procedure exactly opposite to that typically used. For example, perhaps the best way to teach a child the alphabet would be to first get him to say the letter Z. This requires nothing but an echoic (imitative) response from the child. Having emitted the response Z, the child may then be encouraged or given whatever reinforcers are available and asked to say the letters, Y, Z, then X, Y, Z, and so forth. (Or if adding only one letter at a time is too boring for a child, it might be better to add two or three letters at a time; "Say XYZ," then, "Say UVWXYZ," followed by "Say RSTUVWXYZ" and so forth.) If the task were to memorize Lincoln's Gettysburg Address, the instructor could proceed by having the student say, "can long endure." The next step might be to have him say, "so conceived and so dedicated can long endure," and so on. The process would <u>end</u> with establishing the <u>first</u> set of responses in the recitation: "Fourscore and seven years ago." At this time, however, these examples are still provocative sources for research and development. The reader is urged not to take them too literally.

The traditional means of chaining employed in the classroom requires, paradoxically, that some extinction occur as each new step in the chain is added. Perhaps the reason that this method of teaching behavioral sequences works at all is that relearning occurs much faster than original learning. In the usual sequential learning situation, as a new response is added all preceding members of the sequence must be at least partially extinguished since reinforcement is withheld until the new functional unit occurs (i.e., until the new unit which will terminate in reinforcement is formed). The entire process is then quickly relearned with a new terminal response. When a child is taught to say A, then A, B, then A, B, C, he is being subjected to a reinforcement contingency that requires a constant change of the functional response unit. After having been reinforced for saying A, the A response alone is extinguished so that it can be replaced with the response unit A, B, which is likewise extinguished and replaced with A, B, C. On the other hand, if the child begins to learn the alphabet with Z first, from that time on he will (in the ideal case) always be reinforced for what he has previously learned. In backward

chaining of the alphabet, Z is never completely extinguished, but is placed under the discriminative control of the letter Y. In other words, it is possible for the learner to be reinforced when he has emitted some other behavior, in this case Y. Y in turn is placed under the discriminative stimulus of the letter X. In this way backward chaining may prevent the disruption of previously learned responses since continuous discrimination training occurs rather than intermittent extinction.

Backward chaining may also have the advantage of forcing repeated practice of the final members of a response sequence. In fact, the later a response occurs in the sequence of responses, the more practice it has had before the entire sequence is learned. In backward chaining the newest elements, those which have been most recently added and are the weakest, are those which are most strongly and recently prompted by the teacher. Thus, the chances of running off the entire chain at each repetition are extremely good. If the teacher has reached M in the alphabet, he will prompt the child by saying, "Now say _L_, M, N." The new response L is strongly prompted and quickly added to the chain which now may be run off by virtue of prior practice and reinforcement.

The notion of backward chaining suggests a radical departure from standard educational techniques and requires the use of somewhat artificial situations and responses in order to arrive at the terminal behavior. Perhaps in no other instance of the application of learning principles to training technology does common sense seem more challenged than in the method of response chaining. However, demonstrably efficient learning practices may not necessarily be consistent either with traditional practice or intuition.

The Nature of Reinforcement in Chained Behavior

According to one recent theoretical analysis of reinforcing stimuli, the particular event that constitutes a reinforcement is not a stimulus external to the learner so much as it is the behavior produced by the stimulus.[2] For example, it may not be food, but eating that reinforces

[2] Premack, D. Toward empirical behavior laws: I. positive reinforcement. Psychol. Rev., 1959, 66, 219-233.

a hungry person. Thus reinforcers may be defined either in terms of behavior or in terms of stimuli. Either definition may serve a particular purpose and both are useful ways of thinking about the effects of reinforcement.

Regardless of theoretical considerations, the analysis of reinforcement as response rather than as stimulus makes sense with respect to human behavior. It is often not so much the achievement of a goal that seems to reward individuals, as the behavior produced by obtaining the goal. Perhaps the reason why programming seems to increase motivation for working through an instructional sequence, is that through programming it is possible to make one behavior contingent upon another. Instructional material which is not programmed may permit a student to proceed regardless of the nature of his responses to each step in learning.

In any chain of behaviors, the terminal response (the response to the reinforcer) is reinforcing and thus by definition a high strength response, i.e., the probability of its occurrence to the reinforcing stimulus is high. The reason that response chaining works, according to the foregoing analysis of reinforcement, is not that each response produces a rewarding stimulus, but that each response in the chain permits or sets the occasion for a subsequent high strength response. Moreover, whenever a high probability response is dependent upon the occurrence of a lower probability response, the probability of the weak response will increase and approximate that of the high strength response which is dependent upon it.

The net result of these considerations is that it is the <u>response</u> to the reinforcing stimulus, not the reinforcing stimulus itself that is effective in increasing the strength of behavior to be learned. This analysis would indicate that what is reinforcing to a student in a programmed learning sequence is not being told that he is right, but being permitted to engage in another activity. Thus it would seem that the programmer should use as many devices as possible to permit the student to "go on" through the program. What practical difference this analysis of reinforcing events may make in the future of programmed learning remains to be explored.

Motivational Uses of Terminal Behavior

If responding is reinforcing in itself, it follows that the maximally reinforcing response in a learning situation is the performance of the entire integrated chain of behaviors which is the goal of instruction, i.e., the terminal behavior. The reinforcing properties of terminal behavior may be useful early in training to reinforce student interest or in other terms, to enhance motivation. Flying an airplane, for example, consists of many sub-chains which must be acquired by the student and which together form a gross sequence from takeoff to landing. Often flight instructors make a point of letting the student pilot "fly" the airplane by himself the first time up. Objectively, this is not a very significant accomplishment since the plane will fly itself if properly trimmed. For the student, however, it is the terminal behavior he thought to engage in only after long, hard study. Being able to "fly the plane" only a few minutes after instruction has begun can be highly motivating and can provide a basis upon which other less dramatic behaviors may be built. After the initial flying experience, the student's feelings of excitement and accomplishment are likely to generalize to other components of the instructional program, such as map reading, weather, fuel economy, and aerodynamics. Other possibilities for using terminal behavior at the beginning of training are abundant and the difference such a training procedure may make in the student's motivation is great.

In many instances, engaging in the terminal behavior of a task at the early stages of training may be too difficult or too dangerous. In such cases it may be necessary to select only a part of the terminal behavior for initial use. For example, no beginning typist can type 60 words per minute unless it is the same word typed over and over. However, retyping the same word at the same rate an expert types many words may seem very accomplished to a beginner. Often it is necessary to provide the learner with strong external stimulus support, as when a baby learning to walk pushes a wheeled toy ahead of him for support. Of all those concerned with the learning process, it will be the learner himself who is most anxious to be rid of such supports when the training program later shows him how it is possible to get along without them.

The reinforcing properties of terminal behavior should not be promised to the beginner, they should, if possible, be given to him immediately and should be used in the technical sense of a reinforcing event. The foregoing considerations suggest that terminal behavior or some form of it might be included at the beginning of a program or program sub-unit and pre-terminal behavior might be programmed to follow it and lead to its "real" performance.

The reader is again cautioned that these recommendations regarding the initial use of terminal behavior are extrapolations from learning theory which require practical development. In attempting to be explicit the authors take the risk of being wrong on a number of points. However, introducing aspects of terminal behavior early in an instructional program seems logical and is researchable. The motivational properties of early terminal repertoires produced at least in part through artificial means must be weighed against the cost and difficulties involved. It is also true that artificially produced early terminal behavior may give the learner a false sense of accomplishment, but this should not be a serious objection if the program follows through with the teaching of real accomplishment. At the present time and in the light of available research evidence, the foregoing recommendations seem generally sound; in some situations they should be applied with caution, in others with imagination.

Summary

In the course of learning, previously neutral stimuli come to set the occasion for, or control, particular behavior. Stimulus control refers to the fact that a given stimulus, as a result of learning, will consistently elicit a specific response. Such control requires discriminative behavior--the individual must be able to discriminate or select the control stimulus to which he responds, from other stimuli. A discriminative (or control) stimulus comes to control a response because the response is reinforced in the presence of that stimulus and extinguished in the presence of other stimuli.

Stimulus control of behavior is established or modified by judiciously reinforcing or withholding reinforcement. A discrimination can be sharpened by extinguishing responses made to stimuli similar to the control stimulus. Conversely, control can be extended to a broader range of stimuli by closely pairing new stimuli with the control stimulus and reinforcing responses to the new stimuli. Various discriminations can be integrated and consolidated by establishing a new controlling stimulus which subsumes them. All these operations vary, for the most part, only in the conditions which result in reinforcement, but they lead to a great complexity of behavior and appear to be basic in designing instructional procedures.

Just as some responses are determined by control stimuli in the external environment, many responses are under the control of internal stimuli. The term differentiation is used to describe the increasing precision of responses to internal stimuli. Differentiations, like discriminations, can be taught gradually through approximations, but in differentiation training the way in which a response is executed determines whether it is reinforced.

A major characteristic of an expert is that he is able to perform largely on the basis of internal stimuli and, hence, produce self-sustaining chains of responses. Similarly, the goal of a program is to make the student capable of performing self-sustaining chains of behavior. In such behavioral chains each stimulus serves as the reinforcer for the preceding response as well as the control stimulus for the subsequent response.

Traditionally, chains of verbal behavior have been taught in the order in which the chain is performed. In contrast, behavioral chains in the laboratory are formed in a backwards order from the reinforcing event at the end of the chain. Thus the order in which they are established and the order in which they are performed are exactly opposite. This backwards chaining procedure has implications for improving the teaching of human verbal behavior.

It has been suggested that it is the performance of a response that is reinforcing rather than the reinforcing stimulus. Thus, in a sequence of behaviors, the ability to perform a response serves as a reinforcer for the behaviors that occur prior to it. This notion can be used to enhance the beginning student's motivation by allowing him to perform the terminal behavior or some segment of it, early in training. The early performance of some part of the terminal behavior can provide the motivation for learning the behavior leading up to it.

PART III

PROGRAMMING PROCEDURES

Chapter 4: Analysis of Instructional Objectives and Subject Matter Units

The initial problem that arises in starting to build a programmed learning sequence is the analysis and specification of the subject matter behavior to be covered. Before programming can begin, the subject matter must be analyzed into units that can provide the frames or building blocks of the instructional program. The construction of a particular program sequence is a joint function of both the structure of the subject matter and the instructional procedures which best facilitate behavioral goals such as retention or transfer. In any instructional situation, the objectives of instruction must be defined in terms of terminal student performances to permit selection of the most effective instructional methods and materials, the specific subject matter to be taught, and the appropriate instruments for measuring attainment of instructional goals.

Formal procedures for analyzing subject matter knowledge and skills and for organizing the results of such analyses in order to facilitate program construction are still at a crude stage of development. Generally, programming groups employ nothing more systematic than a detailed subject matter outline as a basis for generating sequences of frames. More rigorous techniques need to be developed in the course of continued experience in the field; this chapter describes some current attempts in this direction. In contrast to the later chapters on program construction which are largely detailed self-contained units, this chapter is more general and is keyed to particular references for further elaboration.

Defining Objectives for Programmed Materials

Confronted with the task of constructing a programmed instructional sequence, the programmer needs to know exactly the performance he wishes the student to attain. Several beginning systems have been developed to determine performance objectives and to provide some means for translating these objectives into actual program construction procedures. These systems are concerned with both the subject matter to be taught and the learning principles involved in teaching the subject matter most efficiently.

A General Procedure[1]

The specification of objectives for programmed instruction must be made in terms of behavioral end-products, that is, in terms of what the student must be able to do--the operations he must be able to perform, the words he will be able to spell, the algebraic equations he will be able to solve--when he has completed a program. Stating objectives in terms of measurable goals is the only means of selecting appropriate evaluation instruments to measure the attainment of those goals. Carefully constructed proficiency tests based upon the specifications for instructional objectives are essential in developing and evaluating programmed instruction.

The actual written specifications of the objectives of an instructional sequence can be defined as "an intent communicated by a statement describing a proposed change in a learner."[2] Such a statement should convey to the reader the specific aims of the sequence. An objective is meaningful only to the extent that it succeeds in indicating the goals of instruction exactly as they were conceived by the instructor or course designer. It should be clear enough that another teacher or programmer could teach for and attain the same objective.

A specification of instructional objectives should rule out all possible alternatives to the goal. That is, it should be stated in unequivocal terms that are not open to misunderstanding. To say that at the end of instruction a student must know French, or appreciate music, or understand the mechanics of a television set, permits multiple interpretations. Is he to speak, read, or write French? Is he to play the piano, sing the major scale, or recognize Beethoven's Fifth Symphony? Is he to be able to recognize the parts of a television set from a schematic diagram, replace a burned-out picture tube, or, given a malfunctioning set, be able to locate and correct the trouble? Verbs such as "to know," "to grasp the significance of," or "to enjoy" must be replaced by more definitive statements, such as, "to write," "to solve," "to identify," or "to construct," if objectives of instruction are to be clearly and explicitly defined.

---

[1] Mager, R. F. Preparing objectives for programmed instruction. San Francisco: Fearon Publishers, 1962.

[2] Mager, R. F., op. cit., p. 3.

A statement of instructional goals should also indicate the conditions which will be imposed upon the learner when he has attained the desired mastery--what he will be provided when he performs the desired behavior, what information he will be denied, and under what conditions the task behavior should occur.

The following procedure can be used to delineate instructional objectives in line with these criteria:

1. As a first step, the programmer must specify the behavior that is to be accepted as evidence that the learner has achieved the objective. In order to accomplish this, the statement of objectives should be modified until it answers the question, "What will the learner be doing when he is demonstrating that he has achieved the objective?" If the objective is to solve linear equations, this must be stated clearly and without ambiguity as to whether the student will be asked to solve or derive linear equations. If the student should also be able to derive equations, this should be specified as another goal of instruction. When objectives for an entire course are written in meaningful terms, it is likely that they will consume several pages; the more objectives that are included, the more clearly is the intent of the instructor indicated to the reader.

2. A second step is to outline the conditions under which the desired behavior can be expected to occur. To indicate that the student should "be able to compute a correlation coefficient" may be insufficient. What kind of correlations will the student be asked to compute? Is the correct solution all that is important, or will he be asked to follow a specific procedure? What information and job aids will he be provided: will he be given a list of formulas, or must he work without reference to any outside help? Answers to such questions may make a great difference in the content of instruction and the materials of instruction used. Rather than specifying only that the student must "solve problems in algebra," a more complete statement of objectives might read: "Given a linear algebraic equation with one unknown, the learner must be able to solve for the unknown without the aid of references, tables, or calculating devices."

3. The third step in the specification of objectives is the determination of an acceptable level of performance. It is important to state how well the student must perform to achieve acceptable behavior. Acceptable levels of performance can be indicated by specifying a time limit in which the behavior must be performed, or a minimum number of correct responses, or the percentage or proportion of performance accuracy that will be acceptable. It is to be expected that some students will surpass this minimum standard. Examples of the specification of performance levels might be: "to maintain a minimum typing speed of 50 words per minute for 5 minutes," "to spell 40 words from the following list of 60 words taught during the course of instruction," or "to correctly perform 90% of the following two-digit summation operations."

Once the terminal behavior has been delineated, the clarity of the specified objectives may be tested by the following procedure. Given a defined objective and a set of test situations or actual items developed to measure the objective, each test item should be evaluated on the basis of whether it includes the behavior desired. If certain of the items intended for use can be accepted and certain of them rejected because they are inappropriate, the objective is probably stated clearly. If, however, the objective is stated so generally that all test items can be accepted as valid measures of achievement, the objective needs to be clarified and made more specific. When goals are not clearly defined, it is impossible to evaluate a course or a program effectively, and there is no basis for the selection of instructional materials, methods, or course content. Moreover, unless the goals are those of both instructor and student, tests can be unfair, misleading, and inadequate in evaluating the terminal behavior attained. Obviously, testing must be appropriate to the specified behavior. If an instructional sequence is designed to teach a student the parts of the inner ear as drawn on an enlarged black and white diagram, it does not necessarily follow that the student will be able to identify parts of the ear when confronted with a colored three-dimensional plaster model. With clearly defined objectives, both teacher and student will be able to devote their efforts to relevant activities, and evaluation instruments can be devised to clearly reflect the student's proficiency.

Specifying Steps and Sequences in a Program

In addition to the general procedure for specifying objectives just described, several systems have been developed to analyze both the terminal objectives and the sequence of steps by which the learner goes through an instructional program. These systems are far from definitive and comprehensive, but are initial attempts at systematically organizing subject matter content into a sequence of frames.

The Ruleg System.[3] This system provides a means of analyzing a knowledge domain prior to the development of an instructional program. The Ruleg System is founded on the premise that the verbal subject matter that appears in a program can be classified into two groups of statements, rules and examples. The rules are called "ru's" and the examples "eg's" hence the name "Ruleg."

Definitions of ru's and eg's are relative; sometimes a rule can be an example and an example can be a rule. In general, a rule is a definition, a mathematical formula, an empirical law, a principle, an axiom, or an operating procedure from any area of knowledge. The main feature of a rule is that it is a statement of some generality for which substitution instances or examples can be obtained. An example is a description of a physical event, a deduction or theorem, or a statement of a relationship between physical or conceptual objects. The main feature of all eg's is that they are statements of some specificity derived from more generalized rules. The clearest example of rules and their corresponding eg's are in mathematics. The algebraic statement that $a + b = b + a$ is a rule which summarizes an infinite number of substitution instances, one example being $7 + 2 = 2 + 7$. The latter statement is in turn a rule for an example of such a statement as 7 stones + 2 stones = 2 stones + 7 stones. It is also possible that the initial algebraic statement, $a + b = b + a$ can be an example of a rule in mathematical theory such as $a \circ b = b \circ a$ in which neither the objects nor the operator are specified. It is not difficult to generate illustrations or ru's and eg's in different subject matter areas.

---

[3]Evans, J. L., Glaser, R. and Homme, L. E. The ruleg system for the construction of programmed verbal learning sequences. J. educ. Res., 1962, 55, 513-518.

The first step in constructing a programmed learning sequence by the Ruleg System is the specification of the terminal behavior. The programmer must outline, as precisely as possible, both the responses he wants from the student at the end of the program and the stimuli or clues in the presence of which the student will be expected to make these responses. At this point questions such as those previously suggested in this chapter must be answered. If the student is studying statistics, will he have to produce a formula on his own, or will he have a book available? Is he being prepared to write a short essay comparing two statistical tests or will he be called upon to take a multiple-choice test at the end of the program? With what stimulus supports may the student provide himself while his criterion behavior is being assessed--another student, the instructor, his notes? The construction and form of the program will differ radically as a function of the criterion behavior chosen.

A second step is to write down all the pertinent subject matter rules. A subject matter expert should try to do this without the external support of texts, manuals, notes, or other references in order to free himself from traditional ways of approaching the subject matter. While the subject matter expert may be able to think of nearly all the ru's needed for the program, the programmer writing a new course as he learns it himself may need to systematically explore pertinent references for additional ru's. Each ru should be written on a separate index card in order to facilitate re-ordering and arrangement during later steps.

The third step is to arrange the ru index cards in an approximate order for program presentation. The ordering scheme will be different for different subject matters. Ordering may be according to a continuum of complexity (introduction of simpler ru's first), chronology (as in a history program), spatiality (as in a geography program), or dependence upon other ru's. Interdependent relationships among rules should be carefully considered, because the understanding of one rule may depend upon the mastery of some other rules. For example, ru's defining resistance in an electronics program should be introduced before ru's about Ohm's law, since the statement of Ohm's law involves the definition of resistance.

Step four calls for the construction of a matrix for systematically comparing and interrelating all of the rules. From an instructional point of view, it is this ability to interrelate rules to one another that signifies "understanding" of the material; hence a technique of programming which systematically prepares these interrelationships is of great value. A rule matrix is made by listing all of the ru's vertically down a sheet of paper, and also listing them horizontally across the top of the paper, as shown in Figure 1. Each cell in the matrix represents one possible comparison between ru's, and the matrix permits the ru's of a subject to be systematically examined for similarities, differences, possible confusion, and connections that may exist. The matrix may also lead to comparisons or relationships which have not been previously considered. The upper left corner of the matrix is reserved for the operators which interrelate the ru's. A very general operator such as relation might be used whereby each ru would be compared with every other to determine the nature of their relationship, e.g., "how is ru 2 related to ru 1?" Another useful operator might be discrimination, and ru's would be compared to determine how each ru differs from every other ru. This procedure may facilitate discrimination training when the ru's have certain similarities which can confuse the student. The major diagonal of the matrix relates each rule to itself, and this diagonal is reserved for definition cells. A ru is related to itself by being defined in terms of some previous behavior which the student has and which can be used to make the definition meaningful.

Figure 1. A Rule Matrix

(Operator)	Ru 1	Ru 2	Ru 3	...
Ru 1				
Ru 2				
Ru 3				
. . .				

Step five requires the programmer to generate examples (eg's) for each of the ru's and ru relationships in his matrix. It is mainly through eg's that the student will interact with the subject matter. In addition, eg's are useful in providing practice and review for the ru during the process of attaining the terminal objective. A full range of examples must be used if an adequately generalizable rule is to be learned, including simple examples, complex cases, and instances set in unique contexts. A good rule of thumb for the first eg is that it be the simplest possible non-trivial example, leaving more complex examples for later stages of the program.

Step six is for the programmer to number each cell in the matrix according to a proposed order of presentation. It has been suggested that the intersection of each rule with itself (definition frames) be used to start a sequence. Then the remaining cells are examined to determine which ru's are to be included in the program and which are to be omitted. The cells to be used are numbered sequentially and the numbered ru matrix is used later in assembling the frame sequences in the program. After the cells have been ordered, the programmer can begin to construct frames by judicious selection and combination of the eg's and ru's that have been generated.[4]

Subdivision of Subject Matter Units. Another suggestion for systematizing the programmer's task is somewhat simpler than the Ruleg System.[5] With this procedure the programmer begins by outlining the material to be taught in considerable detail. The outline should consist of 5 to 20 major headings that correspond roughly to the chapter headings of a textbook. The number of headings to be used depends on the scope of the program. Each heading is written on a red index card, and the cards are ordered in some rational sequence. Subheadings under each red card heading are then written

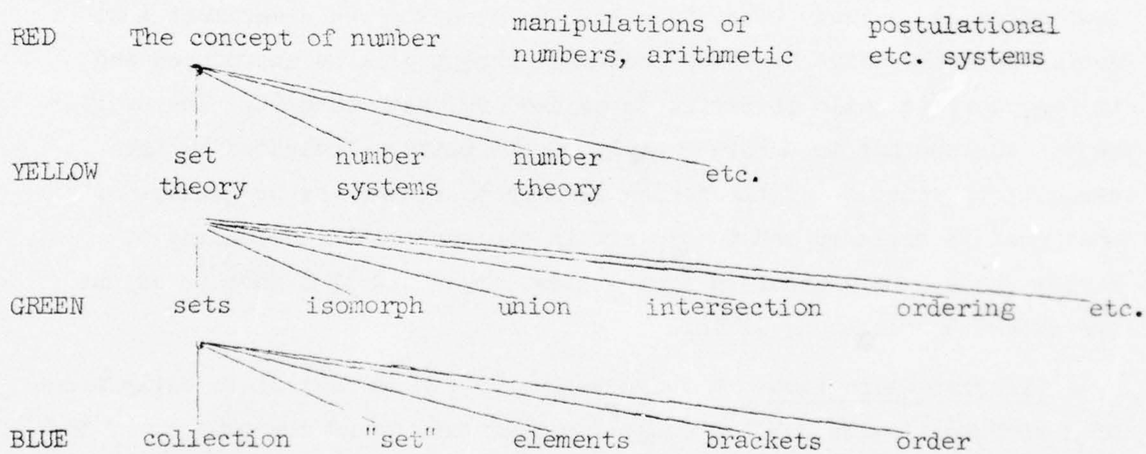
---

[4] Specific frame writing techniques are discussed in Chapters 5 and 6 of this volume, and specific rules for the combination of ru's and eg's are given in the article describing the Ruleg System.

[5] Mechner, F. Programming for automated instruction. New York: Basic Systems, Inc., 1961. (Mimeo.)

on yellow index cards and subsequently ordered. The process of subdivision is continued for two more stages on green and then blue cards. The words, phrases, and concepts written on the blue cards should be the "atoms" of the subject matter, and should be so elementary that a new blue card can be introduced every 5 to 10 frames in a program. This is, of course, an average rate, since several blue concepts might be involved in one frame and some concepts might require more frames than others. To illustrate the subdivision process using set theory, the author of this system given the diagram shown in Figure 2.

Figure 2. An Illustrative Sub-Category Breakdown Used In Subdividing Subject Matter Units



A flow chart is then used to facilitate the introduction and manipulation of the subject matter units. The basic concept of the flow chart centers around the systematic "thinning out" of decreasing coverage of an item after its introduction. For example, three to six consecutive frames deal with the same blue level item when it is introduced. Thereafter, review of that item is interspersed in decreasing frequency among frames for other items. The flow chart in Figure 3 shows how the intensity of treatment is gradually diminished following the introduction of a concept.

Every dot represents a response to be made by the student. Several dots in the same vertical column indicate that the concepts represented will be integrated in that frame. Illustrative frames for the subject matter described in Figures 2 and 3 are shown in Figure 4.

To systematize the planning of a frame sequence, a special stencil or template may be used which automatically thins out the review of a concept according to a predetermined schedule, and varies the rate of review according to the complexity of the concept involved. On the basis of the complexity of the concept, the programmer must estimate what ratios of review frames to teaching frames will be most effective. A difficult concept will require intensive initial treatment and frequent practice and review; a trivial concept will require minimal initial treatment and less frequent review. Prior to using the stencil, the programmer must decide upon the point at which each new concept will be introduced and the appropriate ratio of review to be used for each concept. The programmer is advised not to adhere rigidly to the pattern indicated by the stencil; the purpose of the device is only to remind the programmer of what must be reviewed and to aid him in the systematic scheduling of review items. Data obtained from student tryout is then used to adjust the extent of necessary review.

Discrimination Flow. A third method, which is only at an early stage of development calls for the subject matter expert and the programmer to identify the sequences of discriminations that are required in order to perform the terminal behavior.[6] The specified flow of response units to be taught is set out in a flow chart like the mathematics example shown in Figure 5. The diamond-shaped boxes contain stimulus questions or frame content to which a discrimination is made, and the squares are the appropriate discriminative responses. Beginning with the problem in the

---

[6] Evans, J. L. Programers, experts, and the analysis of knowledge. Paper read at American Association for the Advancement of Science, December, 1961.

Homme, L. E. Teaching machine applications. Paper read at XIV International Congress of Applied Psychology, Copenhagen, August, 1961.

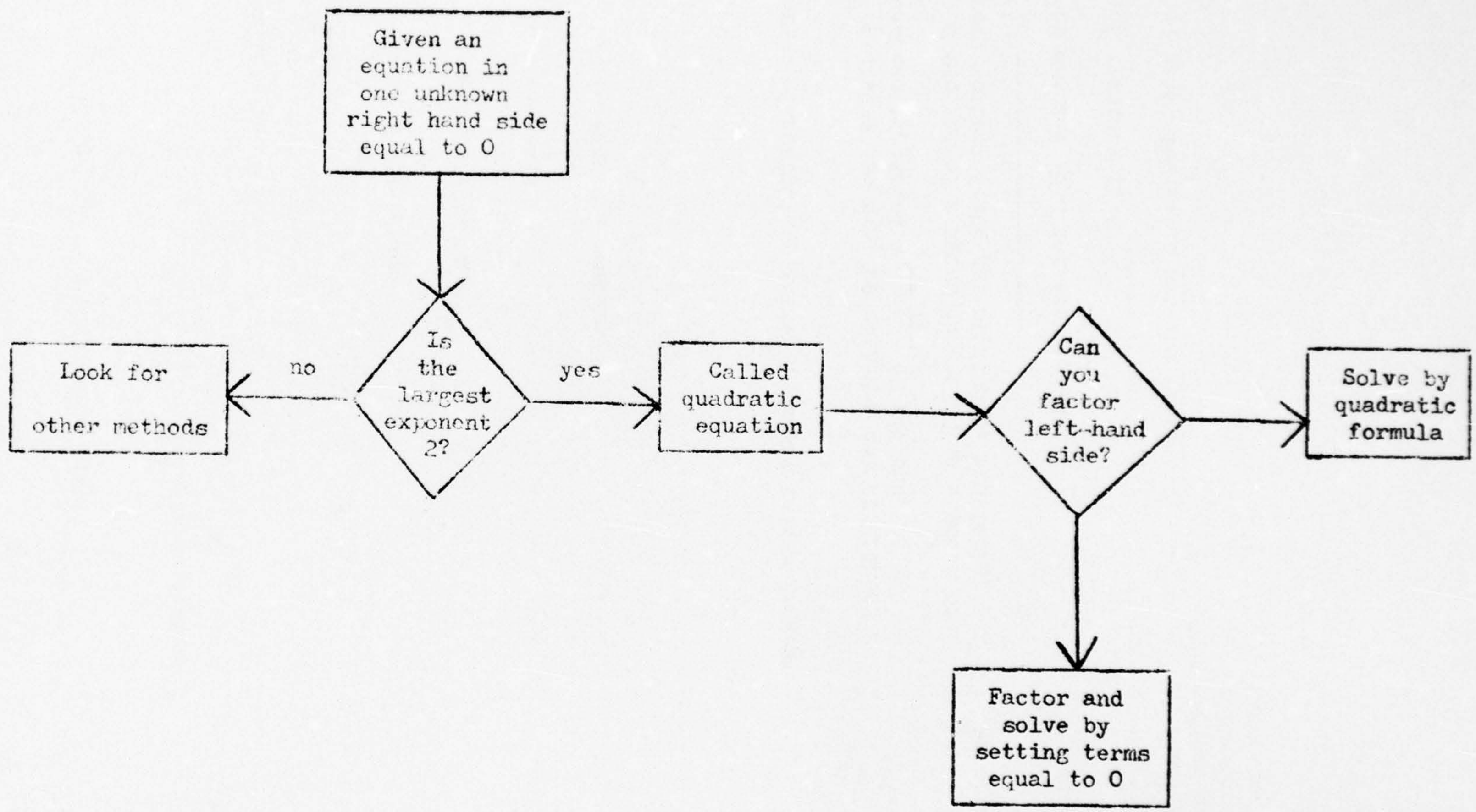
Figure 3. A Program Flow Chart

```
                                             Successive Frames
                            1     5    10     15    20     25     30    35
            collection     ...    .    .         .                         .
             "set"               ...     .      .           .                .
               "set" = collection      ...     .     .      .      .
Blue level
   items         members of a "set"         .....     .   .       .
                  elements                           ... . .         .
                   elements - members                  ... .         .
                    etc...
```

Figure 4. Illustrative Frames in a Set Theory Program

A collection of dishes can also be called a set of dishes. Several crayons can be called a _____ of crayons.	set
Every member of the set of crayons is called an element of that set. Every member of the set of dishes, similarly, would be called ___________________.	an element
In general, the members of a set are called its _________.	**elements**
A collection of elements is a _____.	set
Make a sentence using the words <u>set</u> and <u>element</u>.	A set is defined as a collection of elements.

Figure 5. A Flow Chart in Mathematics



upper box (a type of mathematical equation), a discrimination must be made as to whether the largest exponent is 2. If the largest exponent is not 2, the quadratic method of solution cannot be used. If it is 2, the correct discriminative response is that the expression is called a quadratic equation. The next discrimination involves deciding whether the equation can properly be factored. If the answer is "no," the problem is solved in one way; if the answer is "yes," a different kind of behavior is appropriate. Such a flow chart is made up in conjunction with the subject matter expert and serves as a guide which the programmer can follow and which can be checked by subject matter reviewers. The users of this procedure seem to find that a great deal of behavior can be handled, without too much distortion, in terms of the flow of discriminative responses.

Mathetics. Recently an approach to the construction of teaching exercises similar to programmed sequences has been described under the title of "mathetics."[7] Mathetics is defined as the systematic application of reinforcement theory to the analysis and construction of complex repertoires which represent subject matter mastery. The system is rather technical, and considers behavior in terms similar to those described in Chapters 2 and 3 of this volume. Behavior is generally classified as involving discrimination, generalization and chaining; and the strategy of an instructional sequence is varied as necessary to teach for these three behavioral classes. The unit in a mathetical sequence is called an "exercise" in order to distinguish it from the usual "frame" in programmed instruction. Little restriction is put on the size or extent of an exercise. The size of an exercise is determined not by "breaking the material into small parts," but by determining how big a step a student can reasonably take at the moment. Detailed analysis is also made of the behavior of the student and the responses required by the subject matter in order to determine what courses of instruction might interfere with or facilitate learning. As in the discrimination flow procedure previously described, analysis is made of the discriminations and generalizations required for the attainment of subject matter mastery. The mathetics technique discusses procedures for analyzing the terminal behavior to be taught and planning the sequence of instruction.

---

[7]Gilbert, E. T. Mathetics: the technology of education. J. of Mathetics, 1962, 1, 7-73.

Task Taxonomies

Attempts have been made to develop taxonomies or classification schemes for performance objectives and the development of such classifications of behavior requires further tryout in order to increase their usefulness for specifying the objectives of a training course. This section presents several types of approaches that have been made to this problem of classifying and categorizing instructional goals.

The crucial problem in analyzing terminal behavior is how to describe instructional objectives in a detailed manner that is meaningful for training. In industrial training, job analysis schemes have been employed, but they are not always satisfactory for instructional objectives.[8] For example, one type of job analysis procedure directly infers underlying abilities from observing the job. According to this method, jobs are described in terms of abilities required, such as numerical facility, verbal fluency, color vision, or ability to recall details. These terms, however, are ambiguous and are subject to different interpretations from job to job. For example, the presence of colored signals may not mean that color vision is necessary. The relevant criterion is whether the operator must respond to the presence of a light regardless of its color or whether he must discriminate between different colored signals. The specification of the kinds of discriminations an individual has to make among numerical, verbal, or other visual signals can help pinpoint the skills which must be learned.

Another method of job description comes from time-and-motion study in which physical descriptions of movement are employed, such as "moves lever forward," "loads vehicle," and so forth. This kind of description is convenient to use and is unambiguous. However, it provides no indication of the behavior involved in initiating or terminating the movement. Moving a lever to shift gears in a truck requires different kinds of discriminations from those involved in moving a lever to change the pitch of the rotor blades in a helicopter.

---

[8] Gagne', R. M. Methods of forecasting maintencance job requirements. In Symposium on Electronics Maintenance. Washington: U. S. Government Printing Office, August, 1955.

What the training specialist requires for specifying the terminal behavior of instruction is a set of descriptive categories which tell him how to proceed, since the conditions of efficient learning are undoubtedly different for different tasks. In an analysis of Air Force jobs, five task classes were presented as providing a convenient framework for the description of a great variety of military jobs.[9] These task classes are as follows:

1. Identifying. This means pointing to or locating objects and locations, naming them, or identifying what-goes-with-what--either physically or in words or symbols. This includes much of what is meant by learning "facts."

2. Knowing principles and relationships. This usually means understanding a statement of relationship--as shown by being able to state, illustrate, and recognize its implications. Often this is a statement that tells how a cause produces an effect, or how a result can be predicted from several component factors. It may involve knowing arbitrary rules of contingent procedure, e.g., if such and such is observed, do thus and so.

3. Following procedures. This means knowing how to perform a set of operations that must be carried out in a rather fixed sequence--such as a pre-flight check, starting a car, or making a well-defined type of calculation.

4. Making decisions or choosing courses of action. This usually involves the application of conceptual rules or principles as a basis for making the kinds of decisions that are involved in diagnosing or interpreting complex situations. However, sometimes it involves perceptual discriminations that are learned or acted on directly without reasoning.

5. Performing skilled perceptual-motor acts. These may be quite simple (using basic hand tools) or quite difficult (manipulating the controls of an airplane or performing a sensitive adjustment that requires precise timing). Often the simpler skills provide necessary steps in more complex tasks that require the following of lengthy procedures.

---

[9] Gagné, R. M. & Bolles, R. C. A review of factors in learning efficiency. In E. Galanter (Ed.), Automated teaching: the state of the art. New York: Wiley, 1959. Pp. 13-53.

To refine such a task classification scheme, it is necessary to describe the stimulus and response characteristics of these task classes as well as the learning factors that might influence them and which are relevant to instructional procedures. Knowledge of the ways in which various types of tasks are learned should aid the programmer in pinpointing the training procedures specifically applicable to a particular type of task. A recent manual, for example, describes the kind of training devices and self-instructional devices particularly suitable for the various task categories described above.[10]

Instructional Sequence of Tasks. Once task categories are developed, the next problem is organizing them into units and part-tasks which can be learned in a specifically designed sequence such as a programmed instructional course. A suggested classification of task elements and a tentative (pending more research and development experience) sequence for ordering them in an instructional sequence is the following:[11]

1. System and task requirements data as performance criteria; this is orientation as to the goals of task performance and what the task is all about.

2. Orientation; a general functional flow-chart of the operations supported by task performance and the mechanisms on which it is performed.

3. Nomenclature and identification of work objects and work actions; relating the terms, symbols and work objects to each other so that the student can read and execute verbal instructions, understand feedback, and communicate his actions to others.

---

[10] Lumsdaine, A. A. Design of training aids and devices. In Human factors for system design. Pittsburgh: American Institute for Research, 1960. Pp. 217-290.

Lumsdaine, A. A. Use of self-instructional devices. In Human factors for system design. Pittsburgh: American Institute for Research, 1960. Pp. 291-326.

[11] Miller, R. B. Task description and analysis. In R. Gagne (Ed.), Psychological principles in system development. New York: Holt, Rinehart and Winston, 1962. Pp. 187-228.

4. Search for job-relevant cues; techniques by which the student pays attention to his job environment for cues that indicate he should take some kind of action.

5. Short-term recall; learning to remember task-relevant items of information peculiar to each task or job cycle, or between the perception of stimulus units and motor response.

6. Procedures; acquiring appropriate associations between stimulus events and response actions.

7. Decision making and problem solving; patterns of stimulus variables, response alternatives, goal variables and priorities, and strategy rules for selecting responses; and improvising new responses presented in the form of concepts, mechanisms, or operations to be used in the course of problem solving.

8. Motor response; efficiency and reliability in the mechanisms of executing stimulus-response patterns.

Short-term recall and motor response do not fit into any special place in the order of training; their position in the sequence is likely to be highly dependent on the nature of the task. In general, the order emphasizes the importance of building upon what the student already knows, i.e., successive hierarchies of student competence.

A General Taxonomy. A taxonomy of educational objectives for a wide range of goals in education is described in a book by a committee of educational specialists.[12] Educational objectives are classified in three ways. First, a verbal description or definition is presented for each class and sub-class. Second, each definition is exemplified by a list of objectives selected from materials describing curriculum and achievement test objectives. Third, the behavior described in each class definition is further exemplified by illustrations of examination questions and problems which are considered appropriate to each class. These test questions are considered to be the most detailed and precise definition of the class

[12] Bloom, B. S. (Ed.) Taxonomy of educational objectives. New York: Longmans, Green and Co., 1954.

since they show the tasks the student is expected to perform and the specific behavior he is to exhibit. The important emphasis of this approach is the specification of instructional objectives in terms of items on a detailed test of student proficiency.

Summary

The terminal behaviors which define the objectives of instruction must be analyzed and specified in detail. This permits the programmer to know exactly the performance he wishes the student to attain and the subject matter that must be covered. In general, specification of objectives for programmed instruction must be made in terms of what the student is able to do and the operations he is able to perform when he has completed a program. The specification of instructional goals must be stated in unequivocal terms that are not open to misunderstanding.

The statement of instructional objectives should indicate the following: (a) the behavior that is to be accepted as evidence that the learner has achieved the objectives, (b) the conditions under which the desired behavior can be expected to occur and (c) the acceptable level of performance. Once terminal behavior has been delineated, the adequacy of the specified objectives can be tested by comparing these specifications with behavioral test situations.

Systematic approaches to organizing subject matter content for the preparation of programmed instructional sequences are beginning to be developed. These systems provide ways of breaking down the subject matter into learning units and organizing them into an appropriate flow for initial learning and review. In addition, methods are being developed for classifying and describing instructional objectives in terms of taxonomies or classifications of behavior. Such classifications can pinpoint the training procedures specifically applicable to certain types of tasks.

AD-A031 367 PITTSBURGH UNIV PA PROGRAMMED LEARNING LAB F/G 5/9

A GUIDE TO THE PREPARATION OF PROGRAMMED INSTRUCTIONAL MATERIAL--ETC(U)

OCT 62 J I TABER, R GLASER, H H SCHAEFER AF 33(616)-7175

UNCLASSIFIED NL

2 OF 3

AD A031367

3

367

Chapter 5: The Frame Unit and Prompting Techniques

The Frame Unit

One of the primary characteristics of a present-day learning program is the arrangement of its subject matter into relatively small steps. Such steps, commonly called frames, constitute the smallest units of a program. The construction of these frames is a matter of instructional technology and not merely a matter of subject matter exposition. Moreover, the purpose of a frame sequence is more than just the breaking down of the subject matter into small units for easy learning. While it must be assumed that the subject matter can be analyzed into meaningful units, the mere presentation of these small units does not guarantee learning. Techniques for assuring efficient learning sometimes call for presenting material in a form different from the way in which the material will eventually appear when it has become a part of the student's learned behavior.

There is a hazard involved in defining a frame as a unit of subject matter since frames so defined are apt to be more "instructor-oriented" than "student-oriented." Subject-matter or instructor-oriented frames often tend to be long because the goal in writing such frames is to fully and clearly cover the particular topic. On the other hand, defining a frame as a unit of student behavior implies that a significant component of student behavior is to be brought under appropriate subject matter control so that the behavior occurs in a significant and relevant context. As the student progresses through successive frames, the unit of behavior may be expanded and increased in complexity; thus the student's behavior will gradually approximate the terminal behavior defined by the subject matter expert. From the point of view of instructional technology, it is much better to concentrate on the establishment, expansion, and linkage of response units than on the exposition of subject matter units.

The purpose of the individual frame is to permit the student to emit a response that is some approximation of the terminal behavior, within a sequence that facilitates learning and retention. In supplying the behavior himself, the student is reinforced by displaying behavior that was previously

weak, infrequent, or inappropriate in his repertoire. Reinforcement, derived either from confirmation or from the behavior itself, increases the chance that when the student is faced with a similar situation in the future, he will again emit the desired behavior. The more frequently this basic learning process takes place, the more rapidly the student may approach terminal behavior. Regardless of the complexity of the subject matter, when frames are short and call out only one or two subject matter responses, the active participation of the student is frequent and delays of confirmation or reinforcement are more likely to be minimal. Short frames, but not necessarily simple frames, also help to alleviate the boredom and lack of attention often associated with textbook reading.

Behavioral Requirements of a Frame

To provide an opportunity for learning to occur a frame must consist of certain essential parts. First, it should stimulate the student to engage in behavior relevant to the total behavior to be learned. The most important part of a frame, then, is the response it evokes. The second important feature of any frame is the stimulus used to elicit the student's response. These two aspects of the frame comprise a stimulus-response relationship which already exists in the student's repertoire before he encounters the frame. At times, these two basic components alone may be employed to produce learning. For example, some frames may present two or more familiar stimuli in such a way that the highly probable responses they elicit are combined to produce an unfamiliar response to the stimuli. This new combination of old behaviors may then be reinforced and strengthened. The following is an example of this type of frame:

> The scheme or plan a poet uses to arrange the rhymes in a poem is called a __________ scheme.
>
> Response: rhyme

In this example, the verbal responses, rhyme and scheme, are initially highly probable responses to the stimuli in the frame. This frame requires the student to place the two responses together in a novel arrangement, which would otherwise be a highly improbable response on the part of the student. Another example of the way in which the two components of frame construction--the evoked response and the evoking stimulus--can be used to produce some amount of learning follows:

> A nut  that is shaped like a wing  is easy to turn with your fingers. The proper name for this type of nut is ________ nut.
>
> Response: wing(nut)

Again in this frame, two separate and probable responses are combined to form one new and previously improbable response.

These examples also illustrate a third important feature of all good frames: the response is evoked in the presence of a meaningful context which is usually new to the student. (It is hardly likely that two responses would be put together without some good contextual reason except in humor or drill exercises.) The response "rhyme" was evoked in the presence of a novel stimulus--presumably the student did not previously know that the poet uses a scheme to arrange the rhymes in a poem. The frame was designed to attach the response "rhyme" to the idea of a plan or scheme for ordering the rhymes in a poem.

Most frames are designed to produce responses in a context which is novel to the learner. In the future, this context will tend to evoke the behavior again. The previously learned stimuli used to evoke the response are, of course, discriminative stimuli (S^D), but programmers often refer to them as "prompts." The response under the control of the S^D is the discriminative response, R. The stimulus which a frame attempts to attach to the response or make effective in producing the response is a potential discriminative stimulus. A convenient designation for this novel stimulus in a frame is $\bar{S}^D$. These three elements are evident in the following frame:

> Ice that forms on an airplane's propeller is called propeller ice. Ice that forms in a carburetor is called __________ _____.
>
> Response: carburetor ice

The first line of the frame sets the occasion for the student to behave in a certain way and is the S^D or prompt. "Ice that forms in a carburetor ..." is the situation, or $\bar{S}^D$, to which the student must make the response (R) "carburetor ice." If the programmer found it necessary he could prompt the response more strongly by adding more S^D's for the response:

> Ice that forms on refrigerator coils in called refrigerator ice. Ice that forms on an airplane's propeller is called propeller ice. Ice that forms in a carburetor is called __________ _____.
>
> Response: carburetor ice

Frames may also contain auxiliary material which the author introduces for interest value, clarity, enrichment or continuity between frames. Such extraneous material should be used sparingly and only with justification, but it is often a necessity in order to keep the program literate, interesting and readable. The inclusion of difficult or dull auxiliary material, however, may serve only to teach the student to skim over the material or to hunt backwards from the response blank until he finds the information needed to complete the blank.

Frame construction, then, consists of combining the following elements to produce a learning situation:

1. A stimulus or stimuli (S^D) which serve(s) to elicit or cue the desired response.

2. A stimulus context ($\bar{S}^D$) to which the occurrence of a desired response is to be learned.

3. A response (R) which the student supplies and which adds or leads to the terminal behavior of the program.

4. Extra material which makes the frame more readable, understandable or interesting.

Reinforcement at the Frame Level

In the foregoing discussion of a frame, no mention was made of the reinforcement involved. The reinforcer might well be considered an additional part of the frame, since confirmation is generally used as a reinforcer in programming. As Chapter 3 indicated, however, perhaps the most effective reinforcer in a programmed learning sequence is successfully doing things which could not previously be done. Often the much sought after "joy of learning" can be observed when the learning process results in the learner's ability to engage in behaviors which were previously impossible; it can be fun to learn to drive or fly a plane, to act like an adult, or to solve complex questions. On the other hand, learning techniques often manage to remove much of the fun of learning by placing aversive (punishing) consequences upon not emitting the desired behavior while failing to adequately engineer the situation so that the behavior will occur. The purpose of a frame is to make a response occur, and a good series of frames increases the number of desirable behaviors in which the student is able to engage. In many situations this is a more potent reinforcer than immediate confirmation, and the frame writer would be well advised to capitalize on it in a direct fashion.

The Role of Prompts in a Frame

It is not always necessary for every frame to contain all four of the parts listed. For example, a review frame such as the following might not be designed to establish a new discriminative response and would omit an $\bar{S}^D$:

In chemistry the letters H and O stand for ______ and ______. Response: hydrogen oxygen

Presumably this frame would be preceded by others which would establish appropriate responses to "H" and "O," and would be presented solely to provide the student with review. At other times, prompting S^D's could be omitted if the response were cued by previous frames. Notice that this is true of the second of the two consecutive frames below:

All mammals bear live young. The human bears live young and is a ______. Response: mammal
Birds are not ______. Response: mammals

The first sentence of the first frame cues the response, "mammal," even though many different responses such as "warm blooded" or "mortal" would also be correct. Lifted out of context, the second frame would appear very foolish since obviously birds are not many things. Although the second frame contains only an $\bar{S}^D$ and an R, the correct response is strongly prompted by the preceding frame. Within a series of frames, it is often useful to depend upon the student's momentum or previously established response tendency by means of such interframe prompting. This procedure should be used cautiously, however. After an extended interruption of training, for example, the student's response tendency may be lost and he may make incorrect responses.

A program should guide the student through initial learning with frequent reinforcement and introduce problem situations as the student is ready to attack them. Like a skillful teacher, a program should arrange things so that the student cannot help acquiring new behavior. Special techniques are required in good tutoring; the teacher must lead, direct, question, and prompt the student to behave so that he can be rewarded and encouraged. Similarly, the programmer knows what responses the student must learn and the specific stimulus-response connections to be established; his task is to prompt the student into terminal behavior. A prompt is a familiar stimulus (an S^D, not an $\bar{S}^D$) which used in an unfamiliar context encourages learning the new context. Good prompting is subtle and does not attract attention.

A General Classification of Prompts

A program would teach nothing if the student could fill in the blank spaces without reading the material contained in the frames. At an individual frame level very little is taught if the prompt is so obvious that it is unnecessary to read the new material. At the present stage of development of programmed instruction, however, it is not possible to prescribe the proper difficulty level of a frame, i.e., there are no rules for determining the level or strength of prompting needed. Tryout and revision will continue to be the most useful devices for determining prompting needs until programmers have gained considerable experience with various subject matters. It is possible, however, to describe different types of prompting and to give some general rules about their use.

Generally, prompts are classified as being of two major types--formal and thematic.[1] A formal prompt gives the student a stimulus which he is to copy, echo, or otherwise mimic in form or structure. In essence, the form of the learner's response is identical to the form of the stimulus. A formal prompt is usually a strong cue and seems to be a reliable way of getting the student to come up with the desired behavior. It has, however, certain basic disadvantages which will be mentioned. Formal prompts are

---

[1]Skinner, B. F. Verbal behavior. New York: Appleton Century Crofts, 1957. Pp. 255-259.

used in the following frames:[2]

> A technical word for reward is reinforcement. To reward an organism with food is to __________ it with food.
>
> Response: reinforce

> Photosynthesis really means putting together in the presence of <u>sunlight</u>. In order for a green plant to manufacture food, it must be exposed to ____________.
>
> Response: sunlight

A thematic prompt, as the name implies, depends on the general properties of the prompting stimulus rather than on its exact form. It operates as a cue because of its theme, meaning, associations, and connotations. In contrast to the formal prompt, the form of the appropriate response to any given thematic prompt differs from that of the prompt itself. The following frames make use of thematic prompts.

> The decalogue is a name for the _____ commandments.
>
> Response: ten

---

[2] The illustrative frames used throughout this chapter have been taken from various locations in several different programs. Without seeing preceding frames, the reader may not be able to answer the example frames correctly on the basis of the prompts alone.

Moreover, since diverse frames have been selected solely to illustrate the types of prompts under discussion, a group of frames should not be considered consecutive unless so indicated by the text.

> When the hot wire in a bulb glows brightly, we say that it gives off or sends out heat and ______.
>
> Response: light

It is sometimes difficult to distinguish between formal and thematic prompts. In the following frame, for example, the word "rises" provides both types of cues.

> Just as smoke rises, warm air will also _____.
>
> Response: rise

In general, however, the distinction between formal and thematic prompts is a useful one.

If all prompts used in programmed learning were of the formal type, programs would indeed be open to the charge that they teach only by rote memory. That programs can teach "understanding" is often due to the skillful use of thematic prompting. Because of their strength and reliability, formal prompts are useful in eliciting responses never before made by the learner, such as technical terms or complex symbols. However, the strong formal prompt, if overused, tends to draw attention towards itself and away from the subject material. Formal prompts are generally artificial in the subject matter context and moreover, are not the kinds of prompts available in most tests of terminal behavior. As would be expected from the foregoing, formal prompts are most frequently useful early in a program, whereas thematic prompts are generally more effective as the program progresses.

The use of only a few types of prompts is a frequent characteristic of dull programs. Numerous prompts are available to the programmer, however, and this section presents a variety of examples and applications. For illustrative purposes, the listing of prompt types has been made somewhat specific, but within the two main classes of prompts, there is considerable overlap among types and the categorization is arbitrary. In studying the examples, the reader should remember that a frame may create a very different impression when lifted out of context than when it is within a program sequence. Obviously, the value of any of these prompting techniques can be judged only by its demonstrated efficacy in establishing particular terminal behavior. However, this section can serve as a convenient source for illustration and reference.

Formal Prompts

The Copy Prompt. One way of getting a student to emit a particular response during initial learning is for the teacher to make the response and immediately ask the student to copy the behavior. This is a common means of teaching non-verbal skills such as lathe operation, dancing, mechanical adjustments, and drawing. Similarly, in verbal programming the desired response can often be incorporated in the frame material:

> A check is a promise by a person to pay the amount shown. In place of money, a ________ may be used as payment.
>
> Response: check

The student need only copy the important word or symbol. This device is one of the strongest means of producing behavior for the first time and is valuable when the programmer must introduce a difficult or novel response as a unit. Copy prompts, however, are frequently overused by programmers and in excess tend to make uninteresting programs.

The Partial Response Prompt. Sometimes only the first word of a forgotten poem is enough to cue an entire line or stanza; this is an example of partial response prompting. In verbal guessing games, partial response prompts are often used in the form of hints which give the guesser the first letter or letters of the correct answer. In the same way, a frame which gives the first letter of a desired word eliminates many possible answers and at the same time keeps the frame simple. When the tryout of a program reveals a frame with a high error rate, the introduction of a partial response prompt will often reduce the difficulty level of the frame. Naturally, this prompt should not be used as a substitute for the addition of frames where they are needed or for frames in which the student should respond without the assistance of crutches. As the student's behavior increases in strength, the strength of the formal prompting needed decreases. One way of using the partial response prompt is illustrated in the following frame which is an intermediate step in a sequence designed to teach the spelling of "manufacture."

> Part of the word below is like part of the word manual. Both parts come from an old word for hand. Many things used to be made by hand.
>
> _ _ _ _ f a c t u r e
>
> Response: manu(facture)

The most frequent use, and overuse, of the partial response prompt in verbal programming, however, is in giving the first letter of the response word:

Sociology, anthropology, and psychology all belong to the B_________ S___________.   Response: Behavioral Sciences

The Rhyming Prompt. This type of prompt provides the student with an S^D word which rhymes with the response. For example:

Nine times seven and just one more, is eight times eight or ______.   Response: 64

Of course, the student has already been exposed to the multiplication tables in previous frames.

The rhyming prompt is a formal prompt in the same sense that the partial response is: in order to rhyme with the desired response it must give away at least part of the formal structure of the response. Like other formal prompts, the rhyming prompt should be used judiciously. It should probably be used minimally in programs for adults.

The Literal Prompt. Often a single response may occur in the presence of several appropriate stimuli. Thus both the figure "3" and the word "three" evoke the same spoken response, as do both the symbol "$" and the word "dollar." Whenever the student has been taught to respond correctly to one of several stimuli which call for the same response, his previous learning may be used to extend the response to the unlearned stimuli. A child in first grade learns to read Arabic numerals long before he learns to read the number words. The following examples from a series of frames make use of this in teaching number words:

12

12 t w e l v e 12

12

12 twelve 12

12

twelve

12

twelve 12

twelve

These illustrative frames do not comprise a continuous series, but would be interspersed among other frames for different number-words. In the course of this sequence, the stimulus to which the student can respond correctly (12) is removed gradually leaving only the word "twelve." At the beginning of the sequence, the student is asked to "read" the word (a behavior which he actually cannot perform), but is permitted to depend upon the numerals. As the number prompt is removed over a series of frames, the behavior emitted to the number is transferred to the written word. The name "literal" for this type of prompt refers to the direct interchangeability of stimuli.

The possible uses for this kind of prompt seem quite broad. For example, in teaching symbols or names of machine parts, most people would have little trouble reading the word "resistor," which could easily be transferred to the symbol for resistor by a literal prompting procedure. The emphasis in this type of prompting in a program is to get the behavior to occur in the presence of a new stimulus which will come to control the behavior in the future. Literal prompting, like drillwork, tends to be somewhat barren and uninteresting and is best interspersed with other material.

One interesting variation of the literal prompt may be useful in teaching language pronunciation. An English (previously established) pronunciation is used to cue or prompt the foreign language (to-be-learned) pronunciation. For example, the "a" in German is pronounced like the "a" in "father." If a foreign language is written in unfamiliar characters, as in Russian, the pronunciation of unusual characters may be prompted by a transliteration of the words into English characters. The prompting in the following example approximates the pronunciation of Spanish vowels. The student is first told to read the English words which are written vertically and then to transfer the sound of the vowels in parenthesis to the vowels written between the horizontal lines. Thus, the student reads: "father, break, chief, old, blue." He then reads the vowels as in Spanish: "ah, eh, ee, oh, oo," or an approximation thereof.

	b	c		b
f	r	h		l
(a)	(ea)	(ie)	(o)	(ue)
a	e	i	o	u
t	k	f	l	
h			d	
e				
r				

After some practice with the transliteral S^D's, the student may be asked to say the vowels in Spanish without prompting. This type of prompting may have the advantage of reducing the extent to which expensive equipment is required for the beginning language student. Its great disadvantage in language instruction is that what is learned is only an approximation of native pronunciation, since the transliteration between languages is never precise. A problem also exists in presenting sounds which have no English equivalents, e.g., the Spanish *r*.

Structural Prompts. Frequently the physical arrangement of a frame can be used to prompt the learner's response, thus saving time and words in a program. The location of the response blank, for example, can serve to prompt the type of response desired and minimize the occurrence of alternative responses. In the following frames, the student has been instructed that a response blank on the left calls for a symbol, but a blank on the right requires a word. The position of the response blank indicates, then, whether a word or a symbol is the appropriate response.

Five millimeters would usually be written as: 5 _____.
Response: mm

In the Kelvin scale, zero is approximately equal to -273.1° C. The abbreviation C stands for: ________________
Response: centigrade

The foregoing frames assume that the student has had much previous training. For the most part, these are frames which would appear late in a program.

This kind of prompt is more like a direction to the student than an actual prompt. However, such directions or physical arrangements do provide the student with cues about the response itself. Another structural prompt is the length of the response line. Many programmers use blanks which match the length of the response word, or indicate the number of letters in the response.

Chair factories _ _ _ _ _ _ _ _ _ _ _ chairs.
Response: manufacture

Like the physical arrangement of the response blank, even minor details of typography and format can play an important role in prompting the student's response. The following frames illustrate the way in which the general frame format is effective in cuing the answer. In the first example, a copy prompt is emphasized by placing the response blank directly under the S^D to be copied. Example prompts (to be discussed) in the second frame, are strengthened by providing a sequence of numbers in the second factor of each multiplication: 5, 6, 7, __. Moreover, arranging the example multiplications one under the other makes the number sequence more evident. The drawn arrows in the last example are used to prompt the correct placement of the symbols.

Greece is a peninsula in the Mediterranean Sea.
Florida is a ________ in the Atlantic Ocean.

Response: peninsula

5 x 5 = 25
5 x 6 = 30
5 x 7 = 35
5 x _ = 40

Response: 8

> The <u>M</u>ean is the sum (Σ) of scores ($\underline{X}$)
> divided by the <u>N</u>umber of scores.
>
> Complete the formula for the mean: M = ——
>
> Response: $M = \frac{\Sigma X}{N}$

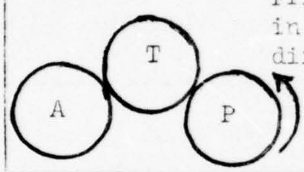
Underlining is another structural detail that has prompting value. Any word in the body of a frame that is to serve as a prompt for the response may be further emphasized by underlining; the first of the preceding example frames illustrates this technique. Although underlining is most frequently used with copy prompts, it is also useful with other prompt types and can serve to point up important thematic prompts. Underlining should be used discriminately and cautiously, however; too frequent usage may render it valueless as a prompt, or encourage students to scan for underlined words without reading.

Simple prompts, such as the frame structure or providing a partial response, often serve to keep frames short and to minimize error rate at the beginning of a learning sequence. In general, formal prompts should be used sparingly since, in contrast to thematic prompts, they do little to enrich the subject matter.

<u>Thematic Prompts</u>

The prompts discussed in this section are, for the most part, matters of narrative, meaning, relevance and connotation. Used skillfully, thematic prompts direct attention to the text and content of the subject matter. The effectiveness of a thematic prompt depends upon associations between various aspects of the student's knowledge and skills. Through such prompts a student is led to interrelate the elements of his behavior in order to extend their meaning and associations to new knowledge. Wise use of thematic prompting can produce a rich and interesting learning sequence.

The Pictorial Prompt. This type of prompt is introduced first because it may be used as either a formal or thematic cue. The interest value of a program may be heightened and subject matter may often be made clearer with a picture placed right in the frame. The picture itself may be used to suggest the answer, or a label attached to the picture may serve a prompting function. The frame below uses a pictorial prompt as a thematic cue.



Friction wheel A is revolving in a ____________wise direction.

Response: counterclock(wise)

On occasion the learner may be asked to reproduce a picture or diagram, as in learning to make the symbols used in circuit diagrams. In such cases, the picture serves as a formal prompt. Perhaps the best use of pictures, however, is in thematic cuing.

Context-Setting Prompts. When an instructor asks a class a question such as, "How is this principle applied in the design of turbine engines?" he is suggesting or setting a context which will evoke student discourse relevant to engine design and not flower arrangement or meteorology. By indicating the topic of conversation, a host of relevant responses assume high strength while other behaviors which are pertinent to other conversations are reduced in immediate strength. In the same way, a frame can be labeled to suggest its context and consequently to limit the range of possible answers. This may be an especially useful procedure when a program covers several topics which must be interrelated or reviewed.

HEARING

The brain "makes sense" out of the impulses carried from the cochlea by the ________ nerve.

Response: auditory

Preceding frames in a program may also serve to establish the context of a particular frame. Part of the text of one frame can be used as the response in the succeeding frame. The two consecutive frames which follow illustrate such interframe prompting.

The fine wire in the light bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of an _________ current. Response: electric
When a weak battery produces little current, the fine wire, or __________, does not get very hot. Response: filament

Semantic Prompts. The grammar used in a frame can restrict the possible answers to that frame. Thus using a specific article, like "a" or "an" rather than the nonspecific "a(n)," limits the number of responses the student can make. The two versions of the frame which follow illustrate the effect of the grammar used.

With grammar prompt:

A candle flame is hot. It is an __________ source of light. Response: incandescent

Without grammar prompt:

> A candle flame is hot. It is a(n) ____________ source of light.
>
> Response: incandescent

The person, tense, and number of verbs may also function as grammatical cues and punctuation can play a part in cuing the response. An answer blank like this, _________, _________, would probably evoke a very different response from one like this, _________-_________.

Synonyms and antonyms may be used to limit the response range by prompting like and opposite responses, respectively. These two kinds of semantic prompts are shown in the following frames.

Synonym:

> Learning usually occurs when an individual's response is promptly rewarded or _____________.
>
> Response: reinforced

Antonym:

> Reinforcement which consists of presenting sought-after stimuli (e.g., food) is called positive reinforcement; reinforcement which consists of terminating unpleasant stimuli (e.g., loud noises) is called ___________ reinforcement.
>
> Response: negative

Just as an antonym may be used to cue a single response word, an entire phrase, statement or concept is frequently useful in prompting a response which is opposite in meaning. This kind of prompt can be seen in the following frame:

> Whereas neural damage in the ascending sensory tracts of the spinal chord will cause sensory deficit, neural damage in the ______________ ______________ ___________ will cause paralysis of the muscles.
>
> Response: descending motor tracts

The redundancy in grammar in a sentence can be a useful cue in a language program.[3] Most meaningful sentences contain redundant parts which can be omitted or replaced by nonsense words without a loss in the reader's understanding of the contents. If the "nonsense" words are words in a language presently unknown to the reader, their consistent use should equate them to equivalents in the reader's language. In other words the usual redundancy which the student anticipates as a result of knowing English grammar and sentence structure, serves as a cue for the responses to be made to the foreign words. Similarly, the grammatical structure of a new language may be acquired to some degree by phrasing the English words according to the grammatical rules of the new language.

---

[3]Schaefer, H. H. A vocabulary program using "language redundancy." Pittsburgh: University of Pittsburgh, 1961. A report issued under Cooperative Research Project 691(9417).

Glaser, R. Some research problems in automated instruction; instructional programming and subject-matter structure. In J. E. Coulson, (Ed.) Programed learning and computer-based instruction. New York: John Wiley & Sons, Inc., 1962. Pp. 67-85.

The following frames illustrate redundancy prompting at three stages of a program introducing German words. The program consisted of stories by Edgar Allen Poe in which German words and word order were gradually introduced. The goal of the program was to equate certain English and German words and no responses were required to individual frames. The first frame below appeared early in the program and introduces some key words. The second frame is from the middle of the program and presents the new grammatical structure. Notice that it is possible to make sense out of the passages in spite of the German words, and how it seems likely that through continued use of the words in the text, the proper meanings will become attached to the new words.

Early:

> True! - nervous, very, very dreadfully nervous, ich, had been, and am; but why will you say that ich am mad? The disease had sharpened meine senses - not destroyed, not dulled them. Above all was der sense of hearing acute. Ich heard all the things in dem heaven and der earth. I heard many things in hell. How, then, am ich mad? Harken! Und observe how healthily--how calmly ich can tell die whole story.

Middle:

> Der second und third day went by und yet showed himself mein tormentor nicht. Again could ich as free man breathe. Das monster was apparently in great terror run away! Never again would ich es see! Meine happiness was complete! Die guilt der black deed disturbed mich but little. Some questions were asked und readily answered. Eine search was even undertaken, but, of course, could nichts be found. Ich looked einer safe future toward.

Late:

Die slope seiner Wände wurde von Moment zu Moment smaller, und der bottom der Vortex seemed sich gradually zu lift. Der sky war klar, die Winde hatten sich died, und der moon went brightly im Westen down, als ich mich auf dem surface des Ozeans facing die coast von Lofoden found, exactly über der place, wo der Trichter des Moskoestromes gewesen war.

The Analogy Prompt. Analogies frequently serve to bring together aspects of a subject matter as well as providing powerful prompts. The method of using such prompts is to present one or more complete analogies in the text of a frame followed by an incomplete analogy to which the student responds. The three consecutive frames which follow, illustrate how an analogy can be used in interframe prompting as well as within a single frame.

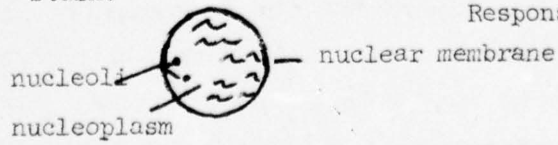
It is easy to learn about the Metric System when one thinks of the money system in relation to it. A dollar has _____ cents (pennies). Response: 100
A dollar has 100 cents. A meter has _____ centimeters. Response: 100
Thus, a centimeter works somewhat like a cent. 100 centimeters is 1 meter just as 100 cents is 1 __________. Response: dollar

The Eliminator Prompt. An effective method of eliminating undesired responses and limiting the response range is to tell the student several of the incorrect answers. An eliminator prompt is a statement which specifically eliminates several alternatives. It is particularly useful in excluding equally appropriate but undesired responses to subject matter stimuli. Combined with another prompt, the eliminator prompt may also be helpful in getting the student to emit an unlikely response early in a frame sequence. The first example frame below combines an eliminator prompt with a copy prompt.

> STRUCTURE-FUNCTION-BEHAVIOR
> Anatomy-STRUCTURE, Physiology-FUNCTION, Psychology-
> ____________.
>
> Response: BEHAVIOR

> A protozoan which moves by means of cytoplasmic projections and has neither flagella (Flagellata) nor cilia (Ciliata) is a member of the class ______________.
>
> Response: Scarcodina

> The nucleus of a cell is made up of nucleoplasm, one or more nucleoli, a nuclear membrane, and chromatin. The __________ is not labeled in our diagram because it cannot be seen without the aid of a special stain.
>
> Response: chromatin



Association Prompts. Old or existing stimulus-response associations can be combined to produce a new or previously low probability response. The example frame below employs the student's existing association between the type of tube used and the name of a radio. By indicating the functional similarity between the transistor and the vacuum tube, the association between tube type and radio name is extended to prompt the correct response.

> A vacuum tube radio is one which uses ordinary electron tubes for reception and amplification. A ____________ ______ is a radio which uses transistors in place of vacuum tubes.
>
> Response: transistor radio

Since technical vocabularies often use common words in unusual combinations, the association prompt may be especially suitable in programming technical material. This type of prompt is best used only when it is readily applicable; combinations of associations which are too contrived may be meaningless to the student and hence ineffective in prompting.

It is possible also to use this prompting technique at an idea or concept level, as well as at the simple word level exemplified in the preceding frame. In this case, independently established thematic elements are put together in a single frame so that the learner gets the feeling of "discovery." For example, after the student has been taught separately the principles of radio operation with vacuum tubes, and what a transistor is and does, a combining frame may lead him to induce the role of a transistor in a transistor radio.

Studies of word association have shown that most people make the same responses or associations to certain words. The programmer can often employ these common associations as response cues. The word, "hot," for example, very frequently evokes the response, "cold." There is always a risk in using this type of prompt, however, since a sizable percentage of people

may make less common responses. Although "mother" will usually elicit the response, "father," this may not be a sufficiently reliable association for use in all situations where "father" is the desired response. In frame writing, the use of existing response chains may be simple--

> In English, the German words Mutter and Vater, mean Mother and ________.
>
> Response: Father

or somewhat more elaborate.

> A penny saved is a penny
>
> Interest on bonds held is part of ________ income.
>
> Response: earned

The important point about these association prompts is that individuals within a given society share many of the same behavioral chains, and these can often be used to prompt a response. Almost all Americans could complete such phrases as, "Now is the time for all good men to ..." or "These are the times that try ..." Although the programmer may depend upon the previous history of the student to establish associations, he can also set up sequences of behavior within the program itself which can then be used to prompt further student responses. It is usually most reliable for the programmer to employ only those associations which he has established himself.

The preceding examples used associations between words rather directly. Associations may also be used indirectly to evoke behavior which in turn serves as the final prompt. Thus the student himself generates the actual

prompting for his response. In the phrase, "Her hair is the color of a fiery sunset," the reader may conclude that the referent has red hair because of previous associations to the words, "fiery" and "sunset." Similarly, responses may be cued by means of word sounds, patterns of emphasis and indirect associations. In the first of the following frames, the words "bright" and "sun" suggest the response, "light." The second frame makes use of an indirect association and, in part, a copying prompt. Because of previous material in the program, the phrase, "unit of electromotive force" in the third frame suggests the term "volt" to the student, which in turn suggests the response, "Volta."

> On a bright, sunny day most of the _______ from the Sun penetrates the earth's atmosphere.
>
> Response: light

> A part of an electrical circuit that is designed to resist the flow of electricity is called a ______________.
>
> Response: resistor

> The name for the unit of electro-motive force suggests to us the name of the Italian physicist Count Alessandro ________.
>
> Response: Volta

The Rule Prompt.[4] Response tendencies may be set up in a frame by stating a general subject matter rule. Usually, such frames present the statement of a rule, followed by an incomplete example of the rule which the student must complete. Rules may also be used to prompt other similar rules. The intention in using a rule as a prompt is not to teach the rule; this may have already been done or may be in process. Rather, the rule is presented only as a cuing device. The following are some examples of rule frames:

> The greatest amount of contrast is presented by complementary colors. Green would stand out best on a ______ background.
>
> Response: red

> $P = \frac{E^2}{R}$
>
> How much power, in watts, is being used up by a 50,000 ohm resistor across which 50 volts are applied.
>
> Response: .05 (watts)

The rule prompt frame exemplifies a deductive method of instruction. Often these frames give the student a feeling of accomplishment because he can make deductions from the rule or predict the results of using the rule in particular cases.

---

[4] Evans, J. L., Glaser, R. and Homme L. E. The ruleg system for the construction of programmed verbal learning sequences. J. educ. Res., 1962, 55, 573-578.

The Example Prompt. Just as a rule may be used to prompt a response, so an example or particular instance may be used to prompt the completion of a similar example or a rule. An example prompt may be called an inductive frame, i.e., from instance to the general case. In essence, a rule may be used to prompt either other rules or examples, while an example may be used to prompt the completion of other examples or the rule which it exemplifies. Some simple example prompts follow:

> A firefly and an electric light are alike in that they both send out or ________ light.
>
> Response: emit

> (-5) (+10) = -50
> (+6) (- 3) = -18
>
> The answers to these multiplication problems are negative because (wds) ______________________________ ______________________.
>
> Response: When a negative number is multiplied by a positive number the answer is always negative.

By leading the student to induce a general rule, example frames can also generate a feeling of discovery like that produced by successful deductions on rule frames. The reinforcement the learner receives in having made such inductions and deductions is valuable in increasing student motivation.

Withdrawal of Prompts

In utilizing prompting devices to evoke appropriate behavior in the student, the programmer is arranging circumstances so that learning can occur. Thus the result of the early frames in a program is the establishment of relatively small bits of behavior in response to rather specific prompting stimuli. As the student's knowledge of the subject matter grows during the course of the program, the strength of prompting should be decreased leaving the student more and more on his own; eventually prompts may be eliminated altogether. Towards the end of the coverage of a particular segment of the subject matter, the programmer should call for increasingly larger and independent units of behavior from the student.

Suppose that the programmer wanted the student to learn the following concept: "The attraction of two bodies towards each other is directly proportional to their mass and inversely proportional to the square of their distance." Such a sentence is only a very small part of a total subject matter, and frames concerned with it would probably be scattered among frames dealing with related material. For this single concept, frames taken from early, middle, and late stages of the program might look like the following.

Early:

> When two bodies in space tend to move toward each other, we say they ________ each other.
>
> Response: attract

Middle:

> The attraction of two bodies is inversely proportional to the ________ of their distance.
>
> Response: square

Late:

> Describe the gravitational relationship between bodies in space. (wds)________________________________
> ____.
>
> Response: "The attraction of two bodies towards each other is directly proportional to their mass and inversely proportional to the square of their distance.

There is no systematic method, however, for specifying the rate at which prompts should be withdrawn. At the present time, the best that can be done is to allow the results of program tryout to suggest what is good and what must be improved.

The terms "vanishing" and "fading" are often used to refer to prompt removal, in general, but prompts may be eliminated in several ways. Increasingly larger amounts of the stimuli which evoke a response may be omitted until only the minimum stimulus remains to evoke a sophisticated response. Prompts may be gradually faded away by being physically reduced in intensity. Still another method is to gradually distort a prompt so that it becomes useless and the student is left increasingly on his own; e.g., prompts may be expanded to a point of non-recognition, shrunk to

illegibility, hidden so that they can by found only with increasing effort, made available to the student upon command, or made contingent upon other behavior. The point in any of these sequential omission techniques is to eliminate the student's dependence upon elaborate teaching supports so that he can behave as an independently functioning expert.

Summary

The frame is a small segment of subject matter which elicits a unit of student behavior. A frame maximizes the occurrence of learning by permitting the student to emit a response that is some approximation of the terminal behavior within a sequence that facilitates learning and retention. A frame creates a learning situation by combining the following elements: a stimulus, a stimulus context, a response, and auxiliary material. The student's response to a frame is reinforced by the successful performance of the response itself, or by confirmation of its correctness.

Early in learning it is usually necessary to arrange for the elicitation of the student's response since as a learner he is unable to behave appropriately to subject matter stimuli. Prompts are cues which evoke previously learned behavior in the presence of new stimuli thus permitting the new stimulus-response combination to be reinforced and lead to new learning. Generally a distinction is made between two major types of prompts. Formal prompts cue behavior by virtue of their structure or form. Thematic prompts serve to elicit a response because of their theme or content. Different applications of formal and thematic prompts have been described.

Prompts are valuable and useful because they permit the emission and reinforcement of new behavior early in learning and as a result make for efficiency in learning. Formal prompts are probably most effective in the initial stages of a program, whereas thematic prompts are increasingly more useful as the learner begins to gain some competence in the subject matter. As the program proceeds and the student's knowledge of the

subject matter increases, prompts should be less strong and reduced in frequency; the student must be able to respond with increasingly larger and independent segments of the subject matter. In the final frames of a program, prompts may be eliminated altogether. The withdrawal of prompts decreases the student's need for behavioral crutches so that he can gradually attain the independent behavior which characterizes knowledge.

Chapter 6: Frame Sequences and Program Characteristics

The modification of behavior through instruction is brought about by many different "learning trials." In other words, the repetition of an increasingly more precise response in appropriate situations is a major condition for learning. In a program, a significant amount of learning can only be accomplished by a series of frames in which a response is called for in many different ways. A program consists of sequences of frames which develop subject matter aspects of a topic and also bring about certain changes in student behavior.

In general, learning programs can differ in numerous major and minor ways ranging from the arrangement of frames within the program, the use of and dependence upon extra-frame materials, structure and format, response mode used, and basic assumptions about how learning proceeds. Characteristics of the program as a whole are probably of more fundamental importance in the learning process than specific frame properties; it is the entire sequence which produces behavioral modifications, the characteristics of single frames merely contribute to this end. Frame sequences, program structural details and extra material should be a part of the program because they have been experimentally shown to add to learning or to facilitate learning.

Special Frame Sequences

Different kinds of frame sequences are required in order to modify behavior in different respects. Considered in this way, frame sequences can be classified in terms of the particular behavioral functions they serve. This section provides illustrations of special frame sequences that are useful in frame construction and seem to lead to specific behavioral outcomes.

Introductory Frame Sequences

Introductory frames allow the beginning student to respond with some behavior with which he is familiar and thus constitute the first building block in a program. The purpose of an introductory sequence is (a) to acquaint the learner with the manner in which the program is written,

(b) to give him some proficiency with the format and display characteristics of the program, and (c) to provide a basis upon which further behavior can be built.

Introductory frames should be very simple and brief, especially if the students have never worked with learning programs. Initial frames in a section of a general science program dealing with sound might resemble the following:

Vibrating objects make a sound. When something vibrates it produces ________.   Response: sound
The strings on a violin vibrate and produce sound. When we speak, our vocal cords ________ to produce sound.   Response: vibrate
The air that surrounds objects picks up the vibrations and carries it to our ears. If there were no air, we could not ______ sounds with our ears.   Response: hear

Introductory frames begin rather quickly to deal with the subject matter and to introduce new discriminative stimuli which are to be learned. Sometimes introductory frames may describe the program:

This is a unit dealing with methods of communication. The word means "exchange of ideas or information." Reading this is one method of ____________.   Response: communication
Communications is spelled c-o-m-m-u-n-i-c-a-t-i-o-n-s. Write the word "communications" carefully.   Response: communications
There are many different ways to exchange ideas. Speaking, writing, and smoke signals can all be used. These are some of the methods of ________________.   Response: communication

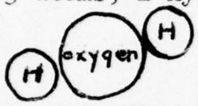
Introductory frames can also give the learner the background information he needs to begin the program. The following sequence from a basic electricity program lays the groundwork for the subject matter to be covered and in addition places the subject in a particular perspective.

All matter is made of molecules. Wood is made of molecules. Water is made of _________.   Response: molecules
A water molecule is the smallest bit of water that could still be identified as water. The smallest bit of glass that could still be identified as glass, is a glass __________.   Response: molecule

A drop of water could be divided in half and then divided in half again and again. Finally only separate ________ of water would be left.

Response: molecules

Molecules are made of atoms. A water molecule has 3 atoms; 2 hydrogen atoms, and 1 oxygen ________.



Response: atom

Discrimination Sequences

As was previously indicated, in behavior theory the symbol S^D stands for a discriminative stimulus to which, by learning, a response has come to be attached or associated. The symbol S^{Δ}, in contrast, stands for any stimulus situation to which a particular response should not occur (see Chapter 3). Much of what the student has to learn in acquiring knowledge of a subject matter consists of discriminations: appropriate responses must become established to subject matter stimuli. For example, to the stimulus, "The astronomical name for the North Star is ...," the student must learn the response, "Polaris." The program first gets him to say the word "Polaris," then he is required to spell it several times, aided initially by a copy prompt and later by less obvious thematic prompts. Following this or along with it the program must equate the terms "North Star" and "Polaris" for the student. In general, this process involves first establishing a response and then putting it under the discriminative control of an appropriate context. Sometimes these operations are best conducted simultaneously and at other times they are best conducted sequentially.

Except during programmer training and for experimental purposes, programmers seldom go to the trouble of specifying each and every S^D and S^{Δ} situation. The process of discrimination training goes on continuously during the course of a program and whatever number of repeated stimulus-response pairings the programmer feels may be needed are interspersed with

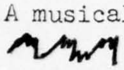
other material in the course of a programmed unit. On particular occasions, however, the programmer may wish to emphasize or give special training in certain important and/or difficult discriminations. To accomplish this, a sequence of frames is constructed to teach the student that a response occurs in one stimulus context and not in another. The frames comprising a discriminative sequence of this kind can occur close together or can be interspersed throughout the program. Figure 1 for example, is a short, illustrative discrimination sequence from the middle of a program on sound. The response "noise" is to be brought under the control of the stimulus "no definite pattern" and for this reason is repeatedly elicited in the presence of this stimulus. A series of frames such as that shown in Figure 1 is usually terminated by a frame which combines both control stimuli, (i.e., noise and music) and calls for a fully discriminated response. Review frames are subsequently seeded in the program to test and strengthen the discrimination that has been established.

As a rule, a program should not contain frames that exhort or admonish the student in such general terms as, "Be sure to understand ..." (it is up to the programmer to make sure the student understands), or "Now remember ..." (that again is the programmer's, not the student's, job). Directions may be valuable, however, in discrimination frames, for example:

Do not confuse kilo and milli. A ____________ is .001 meters. Response: millimeter
Do not confuse kilo and milli. A ____________ is 1000 meters. Response: kilometer

Figure 1

A Short Discrimination Sequence

A musical sound has a definite pattern like this:  All sounds can be classified as either ________ or noise.	music
Noise has no definite pattern to its sound waves. Sounds which do have a definite pattern are called ____________.	music or musical sounds
If we produce sounds with a definite pattern, we can call the sounds ________.	music
___________ is sound that has no definite pattern to its waves.	noise
A high pitched sound with no definite pattern otherwise is called _________.	noise

A series of frames preceding these frames would have already established separate discriminations for kilo and milli. In the frames illustrated above, the directions to the student provide an opportunity to present the words kilo and milli side by side and further sharpen the discrimination between them.

The value of a discrimination sequence is that a learner remembers best what stands out most clearly in the subject matter context, i.e., what has been adequately discriminated. A student typically forgets those associations that he confuses and in fact, the term, forgetting, is often used to describe the confusion of definitions and concepts. An individual may be able to remember all of the material in question, but not be able to attach what he knows to an appropriate context. The student in such a case lacks discrimination training, not an ability to recall material. It is never enough to teach a fact; proficient behavior involves much more and consists largely of the ability to make precise subject matter discriminations. A program should be designed to help accomplish this.

Generalization Sequences

The term generalization refers to the fact that an individual trained to respond in a certain way to certain stimuli, will also tend to respond similarly to similar stimuli. A child who has been taught the label "truck" may also call any other vehicles trucks. While a discrimination sequence is intended to limit the range of stimuli which will evoke or control certain responses, a generalization sequence attempts to broaden the controlling stimulus range.

Sometimes the entire range of stimuli which should evoke a given response is small enough so that it can be included in the program. For example, the number of different objects which evoke the term "American coin" is quite limited and a program could easily be constructed to cover all examples of American coins. For the most part, however, the programmer does not explore the full range of special cases where a general rule or principle applies. To do so would lead to an impossibly long program. The word "valve," for example, is an appropriate response to dozens of different objects. Depending upon the objectives of the program, the programmer could cover a narrow or wide range of valve types. Thus he could program a limited class

such as "aircraft valves" or "valves used in acid liquid flow." In a broader program, the programmer might teach the characteristics of many different types of valves and then present the definition and usage of valves in general.

A generalization sequence might perhaps start and finish with a statement describing the common properties of the stimulus class involved. The programmer should do more than describe such common properties, however; he should arrange the program so that the student will come to emit the general concept by himself. Like other types of sequences, generalization frames need not be consecutive and may be placed throughout a series of frames. Figure 2 presents a sequence in which the concept of "matter" is generalized to several exemplars. In Figure 3, previous training about the summation sign (Σ) is generalized to facilitate teaching multiplication (Π).

The generalization of a response to similar stimuli is an important aspect of learning. A student may be said to understand a rule or concept not when he can recite it, but when he can respond appropriately to examples. Learning to identify and complete instances of a concept often involves extensive discrimination and generalization training.

<u>Chaining Sequences</u>

Skilled or expert behaviors are frequently chains of previously learned responses in which each member of the chain sets up the stimulus context for the following members of the chain. For the beginner, the stimulus context for a given response must be strongly set by the program or instructor. A chaining sequence is a series of frames designed to establish such a complex and self-sustained series of responses. A sequence of chaining frames may start by strengthening individual components of the ultimate chain and end by calling for the student to emit the entire chain. If the student should finish the program with the ability to engage in a self-sustained or preordered series of behaviors, such as counting or reciting, the program should arrange the establishment of such proficiency by means of chaining sequences.

Figure 2

A Generalization Sequence

Matter is anything which has volume. Water is ________ because it has volume.	matter
A stone is also matter because it has ________.	volume
Volume means the amount of space any object occupies. A quart of milk occupies a definite amount of space and thus is a type of ________.	matter
Some forms of matter are invisible. We cannot see air but it is matter because it has ________.	volume

Figure 3

A Second Generalization Sequence

$\sum_{j=1}^{3} x_j$ means to __________ x_1, x_2, and x_3.	add or summate
There is also a symbol that is used to mean <u>multiply</u>. Instead of adding x_1 and x_2, we may wish to _________ them.	multiply
The symbol for multiply is Π or pi (pronounced "pie"). $\prod_{i=1}^{2} x_1$ *means to multiply* _____ *times* _____.	x_1, x_2
$\prod_{i=3}^{4} x_1$ means to __________ x_3 and x_4.	multiply
Σ is the Greek letter for <u>s</u>igma and means to <u>add</u> or find the ______.	sum
Π is the Greek letter for pi. <u>Pi</u> means to ____________, or find the <u>p</u>roduct.	multiply
<u>S</u>igma means <u>s</u> _ _, and Π means <u>p</u> _ _ _ _ _ _.	sum, product
$\prod_{i=1}^{4} x_i = x_1 \cdot \_\_ \cdot \_\_ \cdot \_\_.$	x_2, x_3, x_4

The process of building smoothly flowing verbal chains is central to programming. At the beginning of a verbal chaining sequence, the student engages in a small part of the terminal chain with the aid of many external supports or prompts. As the trainee becomes able to supply more and more of the required behavior himself, prompts may be gradually removed. Figure 4 shows a short chaining sequence designed to teach the rule which defines verse written in iambic pentameter. Usually, the frames in such a verbal chaining sequence would not be consecutive, but would be interspersed with related frames to avoid dull repetition.

In the case of chains which lead to clearly defined solutions or end products, learning theory suggests that it may be good instructional practice to commence the series with the end product and work in reverse order toward what will eventually be the first step in the sequence (see Chapter 3). Figure 5 shows how one might start with the solution of an equation and work the student back to the original equation from which the solution was derived. Having worked back to the original problem, the trainee is immediately required in subsequent frames (the last 6 frames of Figure 5) to go in a forward direction from the problem to the solution. The reader is urged to read the discussion of backwards chaining in Chapter 3 and to study Figure 5 before attempting to include chaining sequences in a program. A good way to become familiar with the method of backward chaining would be to attempt to orally instruct a student in this manner using a simple sequence. After a number of such tutoring experiences the reader should have a much better feeling for the method and its possible use in programming.

Figure 4

A Verbal Chaining Sequence for Learning a Rule

You will recall that iambic feet are accented: _' _' _' The sound you have learned for the iambic foot is _______.	ta TUM
A line that contains five iambic feet is called an ________ pentameter line.	iambic
ta TUM, ta TUM, ta TUM, ta TUM, ta TUM This line is an iambic pentameter line because it contains (#)______ iambic feet.	five, 5
A line that contains ____ ________ ____ is called an iambic pentameter line.	five iambic feet
A line that contains five feet each of which sounds like this, ta TUM, is called an _______ ___________ line.	iambic pentameter
Show the scansion of one iambic pentameter line: ____________________.	_' _' _' _' _'
Define iambic pentameter, (wds)_____________________.	A line that contains five iambic feet, (or similar words).

Figure 5

A Backwards Chaining Sequence

Suppose that we had solved an equation for x and found that x had a value of 5. The solution would be written as ________.

$x = 5$

It makes no difference if we write, $5 = x$. Adding 2 on each side of $5 = x$ we have:

$$5 + 2 = x + \_\_\_$$

2

$5 + 2 = x + 2$. Now multiply each side by 4:

$$4(5 + 2) = 4(\_\_\_)$$

$(x + 2)$

$4(5 + 2) = 4(x + 2)$. Now divide each side by x:

$$\_\_\_\_\_ = \_\_\_\_\_$$

$\frac{4(5 + 2)}{x} = \frac{4(x + 2)}{x}$

$\frac{4(5 + 2)}{x} = \frac{4(x + 2)}{x}$. Now multiply each side by 3:

$$3\left[\frac{4(5 + 2)}{x}\right] = \_\_\_\_\_\_\_\_$$

$3\left[\frac{4(x + 2)}{x}\right]$

$3\left[\frac{4(5 + 2)}{x}\right] = 3\left[\frac{4(x + 2)}{x}\right]$ Now remember that we got what we have simply by adding, multiplying, and ________.

dividing

$3\left[\frac{4(5 + 2)}{x}\right] = 3\left[\frac{4(x + 2)}{x}\right]$ Perhaps this equation would frighten you when you see it like this, but you know that we got it from $5 = x$, the solution. We get it simply by ________, ________, and ________.

adding, multiplying, dividing

(Figure 5 continued)

[The following frames progress in the usual forward direction from problem to solution.]

Here is an equation which might be given to you to solve:

$3\left[\frac{4(5 + 2)}{x}\right] = 3\left[\frac{4(x + 2)}{x}\right]$ To get the solution we would simply undo everything we did before so that again we could get $5 = x$, which is the ____________. | solution

$3\left[\frac{4(5 + 2)}{x}\right] = 3\left[\frac{4(x + 2)}{x}\right]$ The first step in solving this equation for x would be to simplify and eliminate the brackets by dividing both sides by 3. This would leave: ____________________. | $\frac{4(5 + 2)}{x} = \frac{4(x + 2)}{x}$

$\frac{4(5 + 2)}{x} = \frac{4(x + 2)}{x}$ We can further simplify by multiplying both sides by x:

$x\left[\frac{4(5 + 2)}{x}\right] = x\left[\frac{4(x + 2)}{x}\right]$ and cancelling x's on both sides would get: | $4(5 + 2) = 4(x + 2)$

$4(5 + 2) = 4(x + 2)$. Dividing both sides by 4 we get: ____________________. | $(5 + 2) = (x + 2)$

$(5 + 2) = (x + 2)$. Subtracting 2 from both sides we get: ____________________. | $5 = x$

$5 = x$ Writing the solution as solutions normally are written we write: ____________. | $x = 5$

Drill Sequences

Retention and breadth of learning can be enhanced with extensive drill and practice covering variations of basic subject matter rules, operations and methods. As earlier chapters have indicated, practice in varied form and context is a mark of effective programming. The program format affords the chance to eliminate much of the aversive redundancy of ordinary drill since drill frames may be interspersed among other frames and may contain interesting examples. Programmed drill builds up to a point of proficiency at which a majority of students should be able to complete most frames with relative ease and assurance. On the other hand, in ordinary drill many students are left behind because increases in difficulty level are too great or because the students cannot keep pace with other members of the group.

Figure 6 presents three drill sequences taken from a general science program. Again note that the frames of a drill sequence need not be consecutive if the frames are constructed so as not to depend upon close interframe prompting. In general, most drill sequences would probably be found to be additional discrimination, generalization, or chaining sequences.

Review Sequences

Learned material is best retained if practice or review is provided after the original learning. A review sequence is exactly what the name suggests, a series of frames devoted to repeating essential elements of previously learned material. A single review sequence may consist of any number of frames and may review several topics previously covered. Many programmers, however, prefer to sprinkle or "seed" single review frames throughout the program rather than employing special review sequences. This is often done in decreasing density; that is, review of a particular topic is heavy soon after coverage of that topic and decreases in frequency as the student moves through the program. Such seeding of review is intended to meet the requirements of spaced practice which has often been shown to be effective in studies of verbal learning.

Figure 6

Three Drill Sequences from a General Science Program on Measurement

To change centimeters (cm) to meters (m), we divide the number of centimeters by 100. (100 cm = 100/100 = 1 m) 500 cm = ____ m. Centi means ____.	5, 1/100 or .01
600 cm = ____ m.	6
2500 cm = ____ m. 1 meter = ____ cm.	25, 100
250 cm = ____ m.	2.5

Kilo means <u>1000</u>. A kilometer consists of ____ meters.	1000
5 kilometers = ____ meters	5,000
5 kilometers = ____ centimeters	500,000
5 kilometers = ____ millimeters	5,000,000
7 kilometers = ____ meters	7,000
8 kilometers = ____ centimeters	800,000
9 kilometers = ____ millimeters	9,000,000

<u>Milli</u> is a prefix meaning ____.	.001 or 1/1000
<u>Kilo</u> is a prefix meaning ____.	1000
A kilogram is much (larger/smaller) ____ than a milligram.	larger

(Figure 6 continued)

Do not confuse <u>kilo</u> and <u>milli</u>. A ________ is .001 meters.	millimeter (mm)
A ________ is 1000 meters.	kilometer

The programmer should provide ample review material in a program. Even the best program sequence does not eliminate the fact that people tend to forget material they do not use. In planning a review, allowance must be made for the loss of some of the material due to forgetting or interference from subsequently learned material. Thus review frames may also have to re-teach to some extent. For this reason, it is good practice to start an extensive review sequence at a level of difficulty somewhat below that of the last frames in the series being reviewed.

It is often difficult to distinguish between relatively unprompted frames and review frames. In the course of a program, the review frames may blend in so gradually as to be difficult to identify. This, of course, is a characteristic of the sequential nature of programming. Sometimes, however, it is useful to point out review frames by means of a statement such as, "The next 10 frames are review frames." The following are consecutive frames from a brief review sequence.

Let's do a little reviewing: pitch of sound is determined by the __________ of vibrations. Response: frequency
Amplitude is determined by the ________ of the sound waves. Response: height
Things which travel faster than 1100 feet per second are called __________. Sounds with a frequency above 20,000 cycles per second are ____________. Response: supersonic ultrasonic

Terminal Behavior Sequences

Towards the end of a unit of subject matter and towards the end of a program, "expert" or minimally prompted behavior should be required of the learner. This behavior is the goal of the program. Essentially, terminal behavior frames test the teaching ability of previous frames in a program and give the student an opportunity to perform his newly learned behavior. If the error rate on terminal behavior frames is low, it is fairly clear that the program teaches. A high error rate on these frames indicates that earlier frames have not successfully taught and need to be revised. These frames are the one exception to the general rule that frames should be revised again and again until they accomplish their goal in teaching. If experts can agree that correct responses to a given set of terminal behavior frames demonstrate subject matter knowledge, these frames should be the objective of the program and should not be subject to revision.

Sequences Using Extra-Frame Materials

Panel Sequences. Because relatively small space is available on individual frames for pictures or diagrams in the kind of programmed material being described in this handbook, it is sometimes necessary to use a panel when several frames call for the same illustration or figure. A panel is a separate page or card which the student needs in order to respond to a given series of frames. In an anatomy program, for example, a single panel illustrating a particular muscle group might simplify the programmer's task considerably. Similarly, panels may be used to present a page of a financial journal, an electric circuit, a cell diagram, an organization chart, or a table of data. Loosely, a panel is any extra-frame material to be used in the course of instruction; panels may consist of materials upon which the student can draw or write, which he can take apart, or which he is to assemble. The use of a panel may also add to the interest value of a program in much the same way that pictures in a textbook increase attention and interest. Unlike a book illustration, however, a program panel is used only when it is needed to cue or organize behavior so that program objectives are accomplished.

When panels are used, it is important that the student's responding depends in some way on his having examined the panel. A panel should serve as a reservoir of prompts upon which the programmer may draw. If it is intended that the student learn the interrelationships among parts of an illustration, the frames used in conjunction with the panel should foster the student's active response to such relationships. Any kind of frame may make use of the panel material in teaching. Such frames may bear directions for using the panel or may simply refer to it, e.g., "Ask for Panel 25 before answering the next series of frames," or "See Panel 3."

Extraction and Embedding Sequences. There are many occasions in training when a point may be clarified for the learner by artifically extracting a small part of the subject matter from its context or background. In a sense this is a general feature of programmed learning. However, when a student is learning to work with objects and systems rather than with words alone, it is particularly difficult to limit presentation

of visual material to the size of a frame or even the customary panel. Training manuals and textbooks have long used the pictorial method of emphasizing selected sub-systems by the use of shading, coloration, and line width. For example, in learning about automotive engines the student will frequently be given a series of engine diagrams which draw out in turn different sub-systems such as the electrical system, cooling system, fuel supply or piston action. The student is first taught appropriate responses to an isolated or extracted sub-system through a series of panels and associated frame sequences. Subsequently, he is given review and further training in understanding relationships between that sub-system and others by means of a series of embedding panels and frames in which the background is faded back in. Such an extraction-embedding procedure is basically a rather complex discrimination sequence involving the use of pictorial panels.

Programmed "Note-Taking".[1] A frequent complaint made by students learning from a program is that the program leaves them with no notes, such as one might take during a lecture, which can easily be reviewed. To permit such review, it has been suggested that responses to selected frames be written on a special printed note page rather than on an answer sheet or the program itself. The note pages could present a printed summary of the important principles and relationships learned in the program or, depending on the subject matter, might comprise an abbreviated operator's manual. Key words or phrases in the notes would be left blank and filled in by the student as he goes through the programmed material. Appropriate directions would direct the student to place a particular response in a numbered blank on the note page. In this way, the student could construct a systematic outline similar to one he might prepare when studying from a book. A programmed note-taking procedure can serve a useful purpose in showing the student how the subject matter develops its structure as well as providing a means for review.

---

[1] The notion of "programmed note-taking" was communicated to the authors by Mr. Charles J. Stelter of International Business Machines Corporation.

Types of Programs

Programs, like books or teachers, differ in numerous ways. Some programs seem to be direct and matter-of-fact, while other approach new topics with variety and sublety. Such differences among programs are difficult to describe and amount to matters of style and author preference. Other differences between programs are more fundamental and arise primarily from two sources--the nature of the subject matter and different interpretations of how individuals learn most efficiently. This section is concerned with this latter difference and describes some of the distinguishing characteristics of various types of printed programs constructed to date. With further research and development on learning and programming, the relationships between conditions of learning and instructional procedures should become more direct and it should become increasingly more possible to construct programs according to specific procedural rules and logical designs.

Linear Programs

The linear program is by now familiar to readers of this manual. In such a program every student pursues a straight course through the program, responding to every frame, with no deviations or reversals. Students' responses to a frame are immediately confirmed. Most of the linear programs constructed thus far are of the kind suggested by Skinner and employ small steps with relatively few responses called for in a given frame. Linear programs have generally been presented to the student in a programmed textbook or in a teaching machine.

The point has often been made that a linear program is constructed for the average student and as a result may be dull and overly simple for bright students. Eventually, different programs covering the same subject matter may be available for groups with varying levels of readiness, i.e., with different aptitudes and educational histories. For the present, good results have been reported when a wide range of students have taken programs constructed for the average student. Good students finish such programs in much less time than poorer students and are ready sooner for more advanced subject matters. That occurs, of course, if the learning situation is flexible enough to permit full use of the self-pacing feature of programmed learning.

Numerous techniques are available, however, for increasing the flexibility of a single linear program in the face of wide individual learner differences. If research continues to show that frames should be short and require few responses, it would still be possible to introduce the possible advantages of branching programs. For example, the student might be permitted to skip ahead ten or more frames if he comes up with the answer to a certain key "test" frame, or a high error rate could be used diagnostically to direct the student to a series of supplemental frames. Some other devices by which linear programs might be made more adaptable to individual differences are discussed on the following pages.

Branching Programs

In simple branching programs, a correct response allows the student to proceed directly to the next step of a program while errors side-track or "branch" him to supplementary material designed to correct the particular type of error made. Branching may vary in complexity and a simple branching program may merely present a short series of supplementary frames and then return the student to the missed frame. With more elaborate forms of branching, whole sub-programs might be presented to those students who frequently make mistakes on certain kinds of frames, or each branching cycle might be prepared at several levels of difficulty to permit further branching if necessary.

An advantage of the branching arrangement is that it allows the programmer to capitalize on the diagnostic value of errors. Obviously, a student may make several kinds of errors and the type of error he makes may indicate areas of weakness in past training. With branching, the programmer can supply the appropriate instruction to remove the deficiency responsible for the student's error.

Intrinsic Programming. The so-called "intrinsic" programs have made the greatest use of the branching technique.[2] These programs consist of

---

[2]Crowder, N. W. Automatic tutoring by means of intrinsic programming. In A. A. Lumsdaine and R. Glaser (Eds.) Teaching machines and programmed learning. Washington, D. C.: National Education Association, 1960. Pp. 286-298.

relatively long, expository frames with multiple-choice answers. The student first reads a passage and then attempts to answer the multiple-choice question at the bottom of the frame. Each different answer has an associated page number (when the program is in scrambled textbook form) which directs the student to another frame. Incorrect answers branch the student to appropriate remedial sequences. The correct answer directs the student to a page which confirms his answer and presents the next step in the program. Figure 7 illustrates an intrinsic branching program.

Some students and subject matters may adapt well to intrinsic programming. Certain students, for example, may find the expository frame and the multiple-choice answer far more interesting than simple linear fill-in programs. Such a well-motivated student can tolerate larger steps and less prompting than one who is less interested, but unfortunately, few students in a typical classroom may be highly motivated. On the other hand, whenever the terminal behavior or subject matter calls for the assimilation of a mass of information followed by a decision based on several alternatives, the Crowder frame-type seems valuable in at least one stage of the program.

Multi-Track Programs. In a multi-track program each frame is presented in several versions which differ in the amount of prompting used. The same response is called for in all versions. For example, when three tracks are used, the top level or track A contains the version of each frame with minimum prompting. Track B versions present the same subject matter with the response more strongly cued. The greatest amount of prompting is in the C track. Response confirmation does not occur until the student can respond to one of the three tracks. Thus the student begins at level A. If he is sure of his response, he turns to the confirmation and continues to the next frame in the program. If he is unsure of the response, he drops to the version in track B and attempts to respond to it. If he is still unsure, he descends to the track C frame for even stronger prompting before making his response. Figure 8 illustrates a page from a multi-track sequence in a program on matrix algebra.

Figure 7

Four Pages from an Intrinsic Program[3]

Page 101:

Now, you recall that we had just defined

$$b^o = 1$$

for any b except where b = 0. We had reached this definition by noting that our division rule,

$$\frac{b^m}{b^n} = b^{(m - n)}$$

will give b^o as a result if we apply it to the case of dividing a number by itself. Thus,

$$\frac{b^3}{b^3} = b^{(3 - 3)} = b^o$$

but $\frac{b^3}{b^3}$, or any number (except 0), divided by itself equals 1, so we defined $b^o = 1$

We used a division process to find a meaning to attach to the exponent 0. Very well, let's see what other interesting results we can get with this division process. Let's apply our division rule to the case of $\frac{b^2}{b^3}$. What result do we get?

ANSWER	PAGE
$\frac{b^2}{b^3} = b_1$	94
$\frac{b^2}{b^3} = b^{(-1)}$	115
The rule won't work in this case	119

[3]Crowder, N. W. Automatic tutoring by means of intrinsic programming. In A. A. Lumsdaine and R. Glaser (Eds.) Teaching machines and programmed learning. Washington, D. C.: National Education Association, 1960. Pp. 289-291.

(Figure 7 continued)

Page 94: The student who elects page 94 will find:

YOUR ANSWER: $\frac{b^2}{b^3} = b^1$

Come, come, now. The rule is $\frac{b^m}{b^n} = b^{(m - n)}$.

Now, in the case of $\frac{b^2}{b^3}$, we have m = 2 and n = 3, so we are going to get

$$\frac{b^2}{b^3} = b^{(2 - 3)}.$$

So, 2 - 3 isn't 1, is it: It's - 1.

Return to Page 101 now, and quit fighting the problem.

Page 119: The student who elects page 119 will find:

YOUR ANSWER: The rule won't work in this case.

Courage! The division rule got us through b^0, where m = n, and it will get us through the case where m is smaller than n. In this case we have

$$\frac{b^2}{b^3} = ?$$

and applying the rule

$$\frac{b^m}{b^n} = b^{(m - n)}$$

we get

$$\frac{b^2}{b^3} = b^{(2 - 3)}.$$

So the exponent of our quotient is (2 - 3) which is - 1, isn't it?
So just write

$$\frac{b^2}{b^3} = b^{(2 - 3)} = b^{(-1)}$$

as if you knew what it meant.

Now return to Page 101 and choose the right answer.

(Figure 7 continued)

Page 115: *And the student who chooses the right answer will find:*

YOUR ANSWER: $\frac{b^2}{b^3} = b^{(-1)}$

You are correct. Using our rule for division

$$\frac{b^m}{b^n} = b^{(m - n)}$$

in the case of $\frac{b^2}{b^3}$ we get

$$\frac{b^2}{b^3} = b^{(2 - 3)} = b^{(-1)}.$$

Now, by ordinary arithmetic, we can see that

$$\frac{b^2}{b^3} = \frac{b \times b}{b \times b \times b} = \frac{\cancel{b} \times \cancel{b}}{\cancel{b} \times \cancel{b} \times b} = ?$$

So how shall we define $b^{(-1)}$?

ANSWER	PAGE
$b^{(-1)} = \frac{0}{b}$	95
$b^{(-1)} = \frac{1}{b}$	104

Figure 8

A Frame From a Multi-Track Program

S-37 A. The element for the blank space in the following matrix B would be called __________.

Track A:

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \underline{\quad} \end{bmatrix} = B$$

S-37 B. The element for the blank space in the following matrix B would be called ____________.

Track B:

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{\underline{\quad}} \end{bmatrix} = B$$

S-37 C. The element for the blank space in the following matrix B would be called ____________.

Track C:

$$\begin{array}{rc} & \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{\underline{\quad}} \end{bmatrix} = B \\ \text{3rd row} - & \\ & \text{3rd column} \end{array}$$

Confirmation: R-37 ABC: b_{33}

In a standard linear program, the low level frames (tracks B and C) might be a regular part of the program for all students. In the multi-track arrangement, however, they would be used only by those students who need greater prompting. Top level (track A) frames would have relatively high error rates with average students, since each frame step would be large. In contrast, the superior student should be able to proceed through the program solely on track A, thus allowing him to work at a faster and more challenging pace than in the usual linear program. The less able or less well prepared student may frequently experience difficulty on track A, but receives additional prompting in tracks B or C so that he does not make an incorrect response. The procedure minimizes the occurrence of incorrect responding which may interfere with efficient learning.

Practically, the multi-track program differs only slightly from the linear program. The important difference is in giving the student an opportunity to obtain additional prompts before he responds. Variations of this procedure are readily apparent. Multi-tracking might be used only for certain critical frames in an otherwise linear program, or it might be useful in review sequences to which students come with varied amounts of retention. Multi-tracking seems to be a useful compromise between linear and more complex branching approaches to programmed instruction, but at present, it needs to be evaluated further and its potential should be examined.

Most of the implications and possibilities of branching in programming have not yet been explored. The use of a branching technique in no way implies that frames must be long or short or that responses must be multiple-choice or fill-in. In fact, most of the frames in the usual linear program could easily be incorporated into branching programs. Moreover, there is no reason why short and long frames, fill-in and multiple-choice answers, or branching and linear segments can not be mixed in the same program. The choice between linear, brnaching, and other types of programs should hinge upon the nature of the terminal behavior requirements, the sophistication of the student, and the conditions necessary for learning.

Response Mode

Aside from certain subject matter requirements, there are no rigid specifications for the form of behavior a program evokes from the student. Psychologists hold differing opinions concerning response mode, and so far programs have used multiple-choice, true-false, constructed answer, reconstructed answers based upon scrambled material, and labeling. Responses have also been verbal and non-verbal, written and spoken, as well as overt and covert. The majority of the current programs use constructed answer frames, that is, frames in which the student actually writes out his response. Constructed answers have much to recommend them, but the labor of writing out responses often may attenuate the motivational value of a program. On the other hand, the effort of writing may serve to keep some students concentrating on the responses to be made.

Multiple-choice answers are easier to score and permit automation more readily than constructed responses. However, some psychologists point out that the incorrect stimuli in multiple-choice answers may confuse the student or may be incidentally learned and conflict with the correct response. Multiple-choice responses have been used for some time in intrinsic programming. Recently they have also been used with the small step type of programming described in this manual. In one such program which teaches musical symbols a frame might look like this:

> When a sharp is attached to a note, it raises that note one-half step. Which note is one-half step higher than A?
>
> (a) Both (b) and (c)
> (b) A#
> (c) B
> (d) Neither (b) or (c)
>
> Response: (b) A#

Results of several experiments indicate no differences between students who construct responses and those who select multiple-choice responses. In one interesting experiment, children were taught to write numbers even though throughout the course of the program they never actually wrote a number, but merely responded to multiple-choice answers.[4] The children learned to write numbers fairly well, possibly because they had learned the appropriate discriminations which enabled them to monitor their first actual writing during the post-test. Although these small step, multiple-choice programs have not been used to a great extent with adults, they should be equally effective in adult programs.

Another variation in response mode is the possibility of implicit or covert responses to constructed answer frames. It would seem to be most efficient to have the student respond to a frame to himself without actually writing out his response. Experiments have shown that under certain circumstances this can be an effective procedure. However, implicit responding leaves no record of student responses which can be employed to improve and revise the program. In certain programs, overt and covert (implicit) responding can be combined so that the student is required to respond overtly only to certain frames. Such "test" frames also help insure that the student has paid attention to the previous frames. If "working problems to oneself" is an important aspect of the subject matter, a combined frame sequence of this sort might be used to teach the student to respond implicitly.

A program need not consist exclusively of one type of response mode, of course, but can employ various kinds. Although much research concerning response modes is needed, it seems reasonable to employ various modes so as to increase general interest and adapt to a variety of subject matter topics. Most important, a program should call for student behavior that is as close as possible to the expert behavior for any given subject matter. For

---

[4] Evans, J. L. Multiple-choice discrimination programing. Paper read at Amer. Psychol. Assn., New York, September, 1961.

example, since draftsmen are required to produce plans and blueprints, a program for draftsmen must have the student emit this type of behavior. If an expert is required to make decisions between alternate courses of action, then the program leading to expertise must train students to make such discriminations and decisions, and would seem, of necessity, to involve this kind of multiple-choice behavior.

Summary

Learning programs differ in numerous respects: in the frame sequences and extra materials used, in structure and format, and in the response mode employed. All of these characteristics of programs contribute to the modification of behavior and distinguish among programs.

Frames in a program are arranged in careful sequences to provide several learning trials for the learner and to produce specific behavioral outcomes: an introductory sequence elicits the entering repertoire upon which a program can build; a discrimination sequence limits the range of stimuli which will evoke or control certain responses; a generalization sequence extends the range of controlling stimuli; a chaining sequence establishes a complex, self-sustained series of responses; and drill and reveiw sequences enhance retention of learned material.

Various extra-frame materials or panels can be used in a program to cue or organize behavior. A variety of these materials may be used, such as pictures, illustrations and diagrams which the student looks at, a page on which the student draws or writes, and objects which the student takes apart or assembles. Programs can also be arranged to yield a set of review notes or an abbreviated manual by calling for responses on certain frames to be entered on a special note page.

There have been two major types of programs, linear and branching. In linear programs, all students respond to every frame and move directly through the program from the first to the last frame. Branching programs allow the learner to move directly through the program as long as he responds correctly; errors branch him to supplementary material designed to correct the particular type of error made. The major use of branching has been in intrinsic programming which also uses long frames and multiple-choice

responses. This type of program makes use of errors to diagnose weak spots in training and may be more interesting for well-motivated students than linear, short frame programs. For average students, however, the long frames may tend to decrease student participation and create sources of error. Several modifications have been proposed to increase the flexibility of a linear program. For example, a multi-track arrangement, in which three different amounts of cuing are available for each frame, may be a useful compromise between linear and branching programming. In general, research to date has shown no marked advantage for simple branching compared with linear sequences.

Current programs use numerous modes of responding; the most widely used are constructed response and multiple-choice. Multiple-choice responses are easiest to score, but confront the learner with incorrect stimuli which may be a source of competition in learning the correct response. Although multiple-choice answers have been traditionally used in branching programs, they have recently been tried out successfully in small step, linear programs. Constructed responses are most frequently used in linear programs; their major drawback for the student seems to be the labor of writing. In this regard, there is some evidence that implicit or covert constructed responses under certain circumstances may be as effective as overt responding. A program need not employ just one mode of responding; any number of modes may be combined. It seems reasonable, however, to require learning behavior, especially towards the end of a program, that is as similar as possible to expert behavior in that subject matter.

Chapter 7: The Programming Enterprise

This chapter is concerned with the mechanics of constructing a program and the personnel and production steps involved in the process. The production of high quality programs is an enterprise which, if it is to be most efficient, requires capital, equipment, skilled specialists, students for tryout, a well-arranged work space, and the full-time devotion of the principal team members. Usually, many special talents will be employed in constructing a single program; the knowledge and skills of several disciplines are essential in building an optimal program. In such a team approach to program development, there is constant input and direction from subject matter authorities as well as from authorities in learning and training.

The description in this chapter is of a somewhat idealized version of program production. However, successful programs have been prepared by individuals working almost alone. Programs have also been produced by teams structured along lines which differ from those drawn here. Although a good program may be constructed under a variety of arrangements, the following description of the programming enterprise includes most of the general features and problems of production.

Personnel

Program Director

As in any undertaking where a final product will result from the concerted effort of a team, it is necessary that there be one person in charge of the production of a program. This person ought to be familiar with programming procedures and should have a basic knowledge of the underlying principles of learning and behavioral analysis involved although he need not have previously taken part in the production of programs. If insistence were placed upon this kind of experience, it would be difficult, at the present time, to find many suitable persons. Some basic skills which would better qualify the director can be obtained outside of the specific context of programming, such as, skill in and understanding of the methods used in human and animal research on learning, experience in

teaching, skill in writing and editing, and knowledge of general educational methods. Although the program director need not be an expert in the subject matter to be programmed, in the present developmental state of the field much is to be gained by insisting that he be an appropriately trained experimental psychologist.

Programmers

Non-Professionals as Programmers. There is some disagreement regarding who should write the actual frames of the program. One point of view is that subject matter outlines should be written by subject matter experts and subsequently translated into frames by relatively less qualified individuals. According to this point of view, once the subject matter has been specified, any intelligent and competent writer can be given short sections and expected to convert them into frames with minimal instruction. Some who hold this view even say that if a good textbook on the topic exists, programmers guided by rules can convert the parts of the book into individual frames. The cost of labor with this method is relatively low since programmers may be students, experienced secretaries, English majors, school instructors, or professional writers; in short, anybody who can write well.

Even though this procedure has been used, it is well to consider its disadvantages. First, considerable burden is placed on the programming director and subject matter expert in editing each and every frame produced. Second, programmers have to "learn" whatever they are programming either from the subject matter summary or from the textbook they are using. This learning process may be time consuming, depending on the programmer. Moreover, the programmer's limited knowledge of the course material may lead to misinterpretations as to what should or should not be emphasized. Still another limitation is that such programs will be little better than the textbook or the subject matter outline in that any advantages of an interaction between subject matter characteristics and programming techniques may not be realized.

Subject Matter Experts as Programmers. An alternate method is to employ subject matter experts, possibly the same ones who write the syllabus, for the actual programming. Depending upon their eminence this can be a costly process. Again, the programming director will have to edit frames in the beginning of the programming effort and give the programmer the constant feedback which eventually will teach him to write acceptable frames. However, the subject matter specialist will probably quickly grasp the principles involved in frame construction and apply his subject matter knowledge in devising effective frames.

The biggest advantage in using subject matter experts is that the empirical testing of the expert's attempts at programming may help him generate new subject matter organizations which facilitate learning. Such reorganizations would be based upon the subject matter expert's knowledge of relationships in his field, but would also incorporate principles of learning and instructional programming. An additional advantage in using sophisticated programmers is speed; the programmer who is less well versed in the subject matter often proceeds at a much slower rate.

Psychologists as Programmers. It has also been suggested that a psychologist, familiar with behavioral theory, should function as the programmer. The objections that were raised to the non-professional programmer apply as well to the programmer-psychologist. It is true that many existing programs were actually written by psychologists, but these are largely experimental programs which are frequently quite short and cover topics with which the psychologist is familiar.

Regardless of his background, the task of the programmer is to produce frames which will be in turn revised or edited by the programming director. Currently, most programmers need to be trained, and the programming director will usually conduct a training course to familiarize them with basic programming principles and techniques.

Subject Matter Specialist

When it has been decided to program a certain subject matter, the programming director should begin by selecting a person who is thoroughly familiar with it. Preferably, several such persons should be selected since there is seldom complete agreement among specialists. Individuals who can free themselves as much as possible from subject matter conventions should be used. The specialists should become acquainted with the basic ideas of programming and should be told that their influence upon student learning will, perhaps for the first time, be carefully analyzed.

It is often difficult to persuade well-known specialists to work on the development of training materials, but since programming attempts to package the most effective kind of learning for a subject matter it is desirable to obtain the services of the most competent subject matter specialists available. A major attribute of top-notch subject matter experts which is valuable in programming is that they are often adaptable individuals who are not rigidly bound to conventional subject matter organizations or teaching methods. An alternative, however, is to use eminent subject matter specialists to outline the material and review the program in the course of its development rather than to write frames.

Even in dealing with elementary subjects it is always wise to involve experienced teachers and subject matter experts whenever possible. Many insights into student behavior and teaching techniques may be provided by experienced instructors. The subject matter expert, then may be employed in outlining terminal behavior, actually writing frames, reviewing frames for technical accuracy, or in helping to evaluate the program's effectiveness.

Training Specialist

While the subject matter specialist is primarily concerned with the learner's terminal behavior, the training specialist knows what kinds of behaviors trainees will bring to the program. He is a person who has previously taught the subject or has prepared the curriculum for the subject matter. The training specialist is employed in the construction of the program as a consultant. It is his function to specify what the

trainees may be expected to know either about the subject matter itself or about prerequisite materials. For example, in teaching a particular subject matter to students at a given educational level, the training specialist will be able to list the vocabulary which the students may be expected to have and the basic concepts with which they should be familiar. He will also know what common examples have been used in previous instruction and can suggest how these examples might be used in the program.

Editors

Three persons should be involved in the final editing of a program; a psychological editor, a linguistic editor, and a subject matter editor. These editing tasks can, of course, be performed by the same personnel employed in earlier steps of program construction. Much can be gained, however, from the fresh viewpoint of individuals who have not previously worked on the program. A distinction should be made between two levels of editorship. One level is the appending of comments and directions for rewriting frames. At another level is the actual rewriting of frames incorporating those suggestions which the editor has made. Editing and rewriting are functionally distinct and may or may not be done by the same person. Typically, the editors and the program director will edit frames in the first sense, while rewriting is done, for the most part, by the programmers.

Psychological Editing. This refers to the revision of the frames from a psychological point of view, a task performed, to a large extent, when the frames are reviewed by the programming director. The final editing task can be accomplished usually in one reading of the program from beginning to end. The psychological editor attends to such problems as the placement and spacing of review frames, the avoidance of undue repetition, the suitability of discrimination and generalization sequences, the use of examples and rules throughout the program, the use and fading of prompts, and the use of special frame sequences. The psychological editor also prepares a technical description of the frame characteristics and general structure of the program.

Linguistic Editing. It is not a luxury to have a person with specialized writing ability edit all frames for misuse of the English language and awkward wording which can be avoided. A lengthy program takes many hours of the student's time and no effort should be spared to make this time as pleasant as possible. Quite aside from this point, the existing patterns of language are the most powerful tools the programmer commands in communicating ideas. The linguistic editor should, more than others, be aware of subtle differences in wording which might make a meaning clear or a sentence more lively and more instructive. The name "linguistic" editor is used in lieu of a better term; the need is for a professional writer, often a technical writer. However, there are certain literary notions which, because of the nature of programs, should not be imposed upon a program. Repetition, continuity of the text and other such concerns may be of importance in novels, plays, or poetry, but are irrelevant to programs. A writer's strong views in this direction may make it difficult for him to develop an appropriate programming style.

Subject Matter Editing. This editor reads each frame carefully to discover subject matter errors introduced during programming or in the course of revising. Such editing is frequently best accomplished by a person who has not been concerned with the original programming effort, since statements which lead to misinterpretation are seldom caught by the person who originally wrote them. Of course, the subject matter editor must be thoroughly familiar with the subject matter.

Make-Up Director

The format and design used in a program can often enhance the presentation of subject matter and transmit the basic idea in a frame most efficiently. For this reason it is valuable to employ a make-up director who has some training in basic art and graphic design, some knowledge of typography, and familiarity with methods of reproduction. The make-up director functions as a consultant to the programmers and the programming director during the first stages of programming, and is eventually given all of the frames in the program to reproduce in the mode selected for tryout. He should also be responsible for artwork and for the final appearance of the finished program. Although the programming director

decides upon the basic mode of display used for the program, in making final decisions he consults with the make-up director. Another important function of the make-up director is guiding the typists or printer in arranging frames on a page and words within a frame to produce an effective and esthetically pleasing result. It is often difficult for the programmers to anticipate the problems of format and design that arise when the program is reproduced.

Subjects

The Role of Subjects in Tryout. The personnel of primary importance in the instructional programming enterprise are the subjects on whom the program is tried out while it is in various stages of production. At the heart of program development are the data obtained on student performance. A program works if students can display the behavior called for in succeeding steps and can, at the end of the program, perform the specified terminal behavior. In some inadequate programs, it is possible for students to succeed at each step, but fail to attain the terminal behavior. The steps in such a program do not guide the students to the desired performance. Other less than adequate programs may lead the student to the attainment of the terminal behavior, but by means of overly redundant and uninteresting frames.

In essence, the student teaches the programmer what to do next. The student's response to each frame and his final test performance are the measures which guide the programmer in revising the program. Many programmers point out that it is the number of revisions which a program goes through that is important rather than the number of subjects on which the program is tried at any given tryout. The judgment of trainees regarding the frames to which they are exposed will frequently be useful. Comments may be heard such as, "I know exactly what you want to get across here, only I think I could do it much better this way ..." The person in charge of the subjects might well make note of these responses.

Selecting Tryout Subjects. It cannot be stressed enough that a statement of terminal behavior requires knowing who is to perform the terminal behavior. This is not to say that a subject matter which is conventionally taught at a particular educational or aptitude level must necessarily be confined to that level. On the contrary, it appears likely that topics taught by conventional teaching methods in certain grades or training levels can be taught earlier through programming. It is, however, important for the programmer to be aware of the response repertoires of the students that are to be taught. Often programmers try out their programs on available rather than representative subjects. While such informal tryout is useful in discovering glaring errors and carelessness, it cannot tell the programmer how well he has succeeded in reaching the response repertoire of the learner for whom the program is intended.

The more a programmer knows about his tryout subjects, the more he will be able to state about the nature of the resulting program. Although it is frequently indicated that the best policy is to pick subjects of average intelligence for testing a program, the characteristics of the subjects should depend upon the intent of the program and whether it is planned for typical students or is adapted to individual differences by some branching or multi-track procedure. It is important to assess the subject's knowledge of the material with which he is supposed to be familiar (i.e., his existing response repertoire), and the training director should propose appropriate selection methods. In a program on meteorology, for example, it might be wise to ascertain to what degree a student is familiar with certain general physical laws, such as the expansion and contraction of materials due to temperature changes. It may not be so much a matter of aptitudes, age, and specific standing on the educational scale, but the kind of subject matter behavior which the student displays that is important in selecting subjects.

Setting Up for Production

Specifying Terminal Behavior

Initially, the programming director must reach agreement with the person who commissions the program regarding specific and operational definitions of the terminal behavior. The specification of terminal behavior requires a detailed elaboration of what a student should be able to do after completing the course of instruction and should be far more detailed than a curriculum outline (see Chapter 4). Conventional manuals and textbooks covering the material are helpful if there are no standardized criteria of proficiency for the topic to be covered. When the topic is highly specialized or when no sources of information exist, the only recourse is to work with a subject matter specialist, acquaint him with the problem, and ask him to write a course outline which adequately covers the material. Upon completion, the terminal behavior outline should be compared with the demands of the person commissioning the program to avoid any misunderstanding as to what the program should accomplish.

In the process of programming, one or more aspects of the subject matter outline may need to be changed due to the critical analysis made of the subject matter while it is being programmed. These changes can occur in the instructional technique by which a subject matter is to be presented as well as in the amount of material which the program is to contain; conventional sequences of subject matter topics may need to be revised for programming purposes, certain topics may be discovered to contribute little to the desired terminal behavior, explanatory concepts may prove to be ambiguous when analyzed into component parts, and it may be possible to include more advanced notions with very little extra programming work. The commissioner of the program should be aware that such changes in the contents of the program may become necessary once the writing is underway. Failure to reach agreement on the possibility of change during the writing of the program may well result in incomplete or abandoned programs. Experimentation should be taken for granted in the course of program development, since it may lead to ingenious and fruitful ways of accomplishing and re-structuring the objective.

As soon as an agreement between the program commissioner and the programming director has been reached, the terminal criteria should be stated more formally in behavioral terms. This is often done best in the form of a test. Rather than specifying that the student should have knowledge of arithmetic, the goal would be for the learner to be able to solve equations such as $0 = ax + b$, or $0 = ax + by + c$, or "If 5 men dig a hole in 10 days, how long will it take 1 man to dig a hole?" Stating the terminal behavior in these specific performances allows concrete interpretations of the requests to program for either "knowledge" or "understanding." Chapter 4 describes some methods for enumerating and describing terminal performances.

Setting Up the Enterprise

At this time, the programming director must estimate the length of the actual program in order to determine the time, resources, and personnel required to produce it. He may also present a proposal which specifies the terminal behavior and the probable characteristics of the program to the program commissioner. The preparation of the proposal is a sizable effort which involves subject matter experts, extensive reading of subject material, and contacting organizations which presently teach the topic to be programmed.

The undertaking of a programming effort will often take place in two steps: (a) the determination of the terminal behavior on the basis of which required resources can be estimated, and (b) the actual production of the program itself. It is only after the commissioner of the program has approved of the proposal submitted on the basis of the first step that all the final agreements become valid and production can actually begin. Having completed the necessary agreements and established the terminal behavior and the training level of the students for whom the program is to be written, the programming director will proceed to assemble his staff.

Programmer Training

Initial Steps in Training. Typically, the programming director will hold a series of instructional meetings during which he explains basic programming notions and clarifies the programmer's role. One of the best ways to train programmers would be by means of a program on programming. Such introductory programs are beginning to be available.[1] Having programmers read specific books about programming, however, is not necessarily an efficient way to train them. Even the information presented in the discussion period, if learned, may not be generalized to frame writing performance. It seems best to have the programmer start writing frames early in his training; for example, he may be asked to write 25 to 50 sample frames leading to a specified bit of terminal behavior. These frames should be carefully read and rewritten to illustrate good programming techniques. After discussing his work at length with the director, the programmer should revise his own frames or write a new sequence covering the same material.

Editorial Marks. Sometime during the early instruction periods, the director should acquaint the programmers with the techniques he will use in editing their frames. The use of special editorial marks is especially helpful with beginning frame writers and provides an efficient means of interaction between the director and the programmers since the symbols save lengthy explanations. Some illustrative editorial symbols for programming are presented on the following pages.

The wrong response is likely to be emitted to this frame. This symbol may be useful in pointing out that in programming the effort is made to elicit a specific response from the trainee. This effort is related to the effective use of prompts and the strength of control stimuli which influence the reader's response.

---

[1] Markle, Susan M., Eigen, L. D., and Komoski, P. K. *A programed primer on programing*. New York: Center for Programed Instruction, 1961.

~~R~~ The stimulus is too general, possibly no response will be emitted to this frame. This is similar to the preceding instance, but the frame is too general or too ambiguous to elicit a specific response. The differences between ~~R~~ and ~~R~~ should be explained.

R→ A response previously learned to this stimulus material may intrude and produce the wrong response; existing responses are likely to interfere with the desired response here. This symbol often finds a use if the programmer fails to realize that a student brings many associations to a program with him.

-R- The range of possible correct responses is too wide. Sometimes the programmer is not aware of other possible responses the student could give to the frame.

√eg Add an example or example frame before you try to evoke this response.

√ru Add a rule or a rule frame, i.e., a statement of the generalization being taught. At this point it is well to explain the function of rules and examples with perhaps a passing statement about methods for constructing rule and example frames.[2]

~~Q~~ There is no need to state this frame as a question. Let the response emerge in the context rather than as an answer to a question. Beginning programmers have a tendency to ask questions after they have stated something in a frame. There is nothing wrong in proceeding this way except that if done excessively it can become aversive to the student.

Q Insert inquiry or test for terminal behavior. This is equivalent to saying, "Fade all prompts." It is not necessarily an invitation to state the frame as a question, although sometimes this may be appropriate. If the terminal behavior is such that it requires a lengthy response it should be asked for specificially by a question rather than by a complicated completion-type frame.

---

[2] cf. Chapter 5 and Evans, J. E., Glaser, R., and Homme, L. E. The Ruleg system for the construction of programmed verbal sequences. *J. educ Res.*, 1962, 55, 513-518.

! Good use of existing response repertoire. This symbol is a reinforcing editor's mark, general in nature and extremely useful. However, the programming director should explain to the programmers that their reinforcement should come from the fact that the subjects learn and not so much from his opinion. For this reason, they can be told, there are not more rewarding symbols from the programming editor.

n/ Split into separate frames as marked.

W Too wordy.

RR Too many responses. Split into several frames, or limit to one response.

These last three marks all deal with the same problem: the beginning programmer tends to write frames that are much too long. Sometimes a frame is too wordy and needs no more than editing from the point of view of good English. Other frames, however, are overloaded with stimuli and frequently require too many responses for one frame. While there seems to be nothing wrong from the psychological point of view in eliciting several responses in one frame, it often confuses the learner especially at the beginning of a program sequence. It is no more time consuming to have several frames, each of which elicits one response, than to have one frame which elicits many responses.

|R| This calls for a trivial response; response is already at high strength; prompting is too strong. Here the programmer elicits a response which really has nothing to do with the subject matter; responses such as "is," "is not," "and," "yet," or "no." There are times and places when responses such as these should be elicited, but only if doing so is of relevance to the terminal behavior in question.

D Discrimination training. This symbol is seldom used by itself. It may be used with the "split-into-separate-frames-as-marked" symbol already described to indicate that the programmer should insert a series of discrimination frames. This would be suggested when it appears that the programmer has to use more frames to establish a required subject matter discrimination. See Chapter 6 for a discussion and examples of the discrimination sequence.

G Generalization. This symbol also is seldom used without additional instructions. If it is used with the "split-into-separate-frames-as-marked" symbol it indicates that the programmer should insure that the student has explored the full range or total implications of some subject matter principle. See Chapter 6 for examples of a generalization sequence.

wm Warm-up or review frames. Sometimes a programmer assumes that more is retained from a previous section of a program than seems warranted. The warm-up symbol indicates to him that he should introduce a few frames that refer to previously learned material, usually with very little prompting. The symbol is also useful when the programmer has failed to seed review frames.

C Consider use of chaining here. The concept of chaining has been explained in Chapter 3, and examples of the use of chaining in programming may be found in Figures 4 and 5 of Chapter 6.

[m...n] Rewrite frames from *m* to *n*. This is the least specific of the editor's comments. It indicates that nothing can be done with the frames as they exist, they need to be rewritten. Usually such a mark is accompanied by another one indicating the general nature of the change that is needed.

? Subject matter seems questionable, have an expert check.

The symbols listed above may be used by themselves or in combination. Editorial symbols of this kind can eliminate the need for handwritten comments which would otherwise be required. Of course, a little practice with such symbols is required in order for programmers to use them easily, but learning the symbols can be a valuable step in learning the principles and techniques of programming.

Trying Out Programming Techniques. After initial training and briefing, programmers should be rather quickly encouraged to produce frames and have them available for subject tryout. It is a good idea for these early frames to sample various parts of the subject matter under contract to be programmed. Programmers should be assigned small portions of the program's terminal behavior and requested to generate short sequences (50 to 100 frames) leading to the specified behavior. This will permit programmers to deal with different behaviors and the resultant frame sequences can be saved and incorporated in the first draft of the program.

During this time, programmers should also become familiar with the team procedures to be used throughout the programming effort. Thus frames should be dictated, typed, given back to the programmer for revision, retyped, given to the programming editor, given back to the programmers, redictated or retyped, and finally, given to the subjects. This sequence should become automatic for all members of the team.

Generally, novice programmers take a long time to write a frame and their early frames are longer than they need to be. It has been found useful to employ a piecework method in which the beginner is told to produce a certain number of frames per hour. The figure used will depend on previous experience and may vary from as few as 8 frames per hour for complex subject matters to as many as 30 frames per hour for relatively simple subject matters. It should be pointed out that the conventional notions about what is simple and what is complicated do not always hold when a subject is analyzed into frames. Teaching children to tell time, for example, may be much more complicated from a programming point of view than teaching matrix algebra or the fundamentals of electronics. Setting a standard number of frames to be completed per unit time may also encourage programmers to write short frames.

Subjects should be regularly available to use the materials the programmers develop; a period of about two hours a day is highly desirable. A record should be kept of the materials given to each subject, since even after working through a poor sequence, subjects can no longer be considered naive. Between five and ten subjects is a sufficient number for trying

out frames at this stage. When a frame sequence has been tried out, the programmer uses the subjects' responses and comments as a guide in revising the frames. The task is to analyze the subjects' responses and to try to understand the conditions which prevented them from learning, and then to rewrite the frames accordingly.

After the first subject tryout and subsequent rewriting, the revised frames should be tried out once more on appropriate subjects, and if necessary, rewritten until the subject matter is learned as indicated on a short test of the terminal behavior. At this point, a sequence may be considered to be in a first draft form. Frames should then be filed until an integral unit of the subject matter has accumulated.

Program Production

So far in this description of the programming enterprise, the administrative groundwork has been laid, programmers have become familiar with frame writing procedures, and have tried out sequences of frames on subjects. They have also accumulated several units of frames which represent a part of the programming effort. Once the programmers are proficient, the remainder of the programming task is usually approached sequentially. For course-length programs, the terminal behavior can be divided into segments to be programmed by different individuals; the editors can assure continuity between segments of the program.

First Editing

After tryout and revision, consecutive frame sequences are grouped into units of 100 to 1,000 frames and given to the editors. As was previously indicated, these units of the program are edited by three different editors: a psychological editor, a linguistic editor, and a content or subject matter editor.

Before editorial changes are made, they should be reviewed by the programming director. He should have the final decision as to whether suggested changes are to be incorporated because the suggestions of the technical expert or the writer specialist must sometimes be reconsidered. It may be necessary for behavioral reasons to make a statement about the subject matter which taken out of context is incomplete. The subject matter

specialist may forget that this incomplete statement will later be elaborated upon and should not be judged out of context. In a mathematics program, for example, he is likely to criticize the introduction of a matrix which does not have the lines or brackets on the sides to indicate that it is a matrix. Yet this may not be an unreasonable procedure at all when later frames teach the student that an array of numbers without these lines should no longer be considered a matrix. To have presented this information earlier in the program would place too sudden a burden upon the student. The technical editor should understand this method of proceeding and function mainly to prevent technically incorrect terminal behavior from being established. The linguistic editor, too, may find that a program violates some of his principles. Extensive repetition, although alien to good writing procedures, may serve a definite function in a program, such as connecting one stimulus with a set of related stimuli in the course of a discrimination or generalization sequence.

After editing and subsequent review by the programming director, the make-up director is consulted and the format to be used in the program is decided upon. Like the editors, the make-up director may make suggestions regarding the program. It may become apparent that extra panel material proposed by a programmer should be incorporated into pertinent frames, since it is only rarely referred to. On the other hand, it may be advantageous to introduce additional reference panels, consequently changing particular sequences of frames.

The programming director may make certain major changes on the basis of the comments made by the editors and the make-up director. For example, the order in which the subject matter is presented may be changed, or certain frame sequences may be more efficiently programmed. If revisions are drastic, it is necessary to repeat the production process to this point. If, however, the program unit is in good enough condition, it is passed on to the make-up director to be prepared for subject tryout.

First Program Tryout

The sample of subjects who take the program at this stage is carefully selected to conform to the eventual user population. From 15 to 40 or more subjects should be used. In contrast to the previous short sequence tryouts, subjects should be tested on a suitable diagnostic performance test after completing the program unit. The training director should be asked to provide or develop appropriate testing instruments. For some subject matters where previous student exposure is difficult to specify, it is desirable to give a test prior to the program. Testing the subjects before and after taking the program provides a baseline against which student performance can be assessed if necessary.

After the tryout, the frames are again analyzed and the success with which terminal behavior has been attained, as indicated on the test, is determined. The post-test given to the trainees can be analyzed in terms of total or part scores and the results summarized. The analysis of subjects' responses can be made in various ways, but should at least yield a tally of the frequency with which each frame was missed and a list of common errors made on poor frames. A high error rate on a particular frame points to a need for revision, and the types of errors made indicate how the revision should proceed. Moreover, seeing the reasons for student errors can be highly instructive for both programmers and editors.

What will typically exist after the response analysis is a copy of each frame with a brief summary statement of the subjects' responses in a form such as "2/15; 9 electrical energy; 4 electricity; correct response, energy." This notation indicates that 2 out of 15 subjects gave the correct response "energy," 9 wrote "electrical energy," and 4 responded with "electricity." In addition, the annotated copy of the program should contain a statement by the person who had contact with the subjects summarizing any student comments. These materials together with the test results are reviewed by the programming director who decides whether the program satisfactorily teaches the terminal behavior or whether further revision is required. This decision is primarily determined by the extent to which the program has enabled the students to perform well on the test of terminal behavior.

Second Editing and Processing

Sometimes it is evident that the terminal behavior, as outlined, cannot be achieved by the method of programming originally proposed, or can be achieved best by another method. For example, in teaching general science for a junior high school, it seemed advantageous to program the subject matter by topics. Implicit in teaching the topics was the assumption that certain common notions would be learned in all topics. In the test for the terminal behavior it was found that students gained satisfactory knowledge about each topic, but were unable to generalize the concepts which the topics had in common. Thus the tryout revealed that it would have been better to break the whole program into sub-units by concepts rather than by topics. The empirical nature of programming may make it necessary to revise, sometimes extensively, past methods of teaching the subject matter. In such cases, the programming agreement may need to be changed and additional work will be necessary to complete the project.

If the programming director and his editors are satisfied that the terminal behavior has been achieved in the tryout, the business of detailed editing may proceed to prepare the program in its final form for the user. This stage of editing requires attention to every word, comma, period, and semicolon in each frame. Since the student's response is so carefully guided in programmed learning, the consequences of typographical errors are much more serious than in a conventional textbook. After this second editing and proofreading, the programming director will consult closely with the make-up director for the final preparation of the program.

Preparing the Program Format

Programmed Textbook Format. This book has been primarily concerned with programs of the paper-and-pencil, constructed response type. The possible modes of presentation are discussed here in relation to this kind of program. Although such programs may be prepared for a machine when this provides increased learning efficiency, the most simple way to present these paper-and-pencil programs is, of course, in book form, i.e., as a programmed textbook. When this mode of presentation is used, it is necessary to plan the arrangement of frames within the book. During tryout and early stages

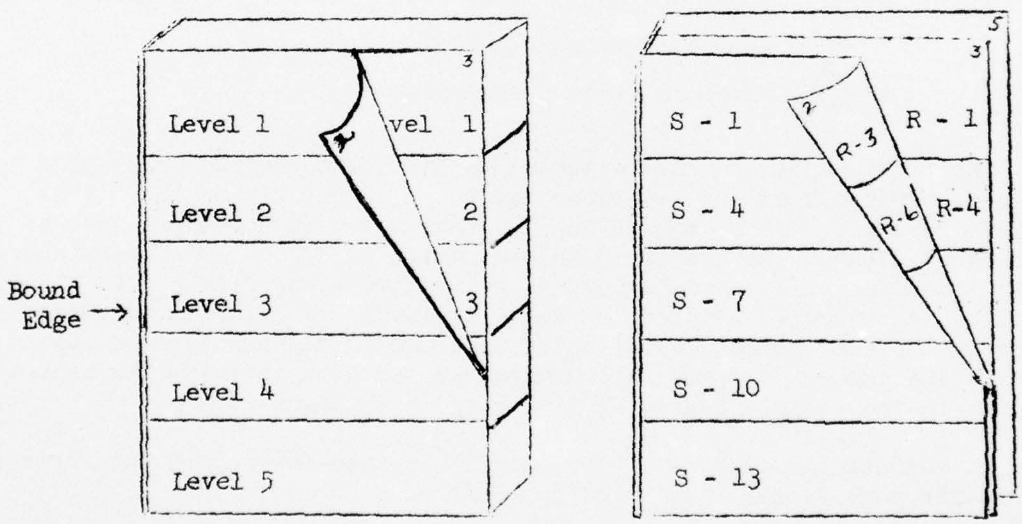
of production, of course, frames need not be in the final format; they may be arranged sequentially on a page like a book, they may be on paper strips for use with certain machines, or they may be on separate cards.

A typical linear programmed textbook format makes use of two types of pages: the stimulus frame or question page and the response confirmation frame or answer page. These pages may be arranged in one of two ways in a program. The response confirmation may be placed (a) on the back side of the page containing the stimulus frame, or (b) on the second page following the stimulus frame. In the first case, if the stimulus frame is on page 1, the response to that frame would be on page 2 and the next frame would be on page 3. With the second arrangement, if the stimulus frame is on page 1, the response would be on page 3, and the next stimulus frame would be on page 5. In other words, the consecutive stimulus frames are on alternate odd pages of the book. A possible disadvantage of arrangement (a) is that the response confirmation for a preceding frame may serve as an unwanted prompt for the next frame since they are on opposite pages. The second arrangement (b) eliminates this problem and for general illustrative purposes the remainder of this section will discuss this sort of arrangement.

In the programmed textbook format to be discussed, a sequence of frames runs from the front to the back of the book and then forward again in different "levels" (see Figure 1). The stimulus frame pages and response frame pages are divided into levels in order to save space. Stimulus frame pages are always alternated with response confirmation pages. On top of the first page then is stimulus frame (S) number 1, and on top of the third page is the answer or response (R) to frame number 1. Similarly, on top of the fifth page is frame number 2 and the response to that frame appears at the top of the seventh page, and so on to the end of the book. When the back of the book is reached at the top level, only the right hand or odd numbered pages have been used. The succeeding frames run towards the front of the book on the top level of the left hand, even numbered pages. When the front of the book is reached again, both odd and even pages in the first level have been used. The next frames are placed on

the right hand pages of level 2, continue to the back of the book and then forward again on level 2 of the even numbered pages. This arrangement--from front to back to front again--continues through each level of the book. Figure 1 illustrates such a programmed textbook.

Figure 1. The Plan of a Programmed Textbook



Useful Formulas in Making Up A Programmed Textbook. Planning the layout of the programmed textbook just described is not as easy as it might appear. With several hundred frames and several levels, it would be most time consuming to determine the number of pages required and location of each frame. The position of stimuli and responses in this type of program can be computed using the formulas presented on the following pages. In discussing the layout of pages in a programmed textbook it is important to distinguish between sheets and pages. The number of sheets in a book is the total number of pieces of paper; the number of pages in a book is exactly double that of the number of sheets. The first sheet in a book contains page 1 on its first side and page 2 on its second side.

If the frames to be put into programmed textbook format are on individual slips of paper, it is possible for the make-up director to assemble the frames in a layout form for use in final typing or typesetting. When the make-up director can compute which stimulus frames to place at each level on page 1, he can then assemble the layout from front to back at all levels at once. The formulas which follow permit determining which stimulus frames (S) should go on page 1 and which response frames (R) should go on page 2 of the first sheet of a programmed textbook. The following symbols are used in the formulas:

T = the total number of frames in the program (for the computations it must be evenly divisible by L, see below).

L = the total number of levels on a page.

n = the number of the particular level under consideration.

S_x = stimulus frame number x.

R_x = response frame number x.

The total number of sheets needed to lay out a program or program sub-unit may be found by dividing the total number of frames by the number of levels. If a program has 100 frames and is to be put into a five-level format, the number of sheets needed is T/L or 100/5 = 20 sheets. If T/L does not yield a whole number, additional blank frames must be added to obtain a corrected T which is evenly divisible by L. This corrected T value is the one the make-up director will use in calculating the layout of pages. The number of pages in a programmed textbook is twice the number of sheets; in the example above, 2T/L or 200/5 = 40 pages.

To compute the numbers of the stimulus frames for page 1 and response frames for page 2, use the following formula:

Formula I. For any level, n,

Page 1: S frame number equals $\frac{(n - 1)T}{L} + 1$

Page 2: R frame number equals $\frac{nT}{L}$

When T/2L is a whole number, the following formula may be used to determine which response frames should go on the second to the last page (right-hand) and which stimulus frames should appear on the last page (left-hand) of the book.

Formula II. For any level, n,

Second to last page: R frame number equals $\frac{T}{2L} + n - 1 \left(\frac{T}{L}\right)$

Last page: S frame number equals $\frac{T}{2L} + n - 1 \left(\frac{T}{L}\right) + 1$

If, on the other hand, T/2L is a fraction, use the following formula:

Formula III. For any level, n,

Second to last page: S frame number equals $\frac{T}{2L} + (n - 1)\left(\frac{T}{L}\right) + .5$

Last page: R frame number equals $\left(\frac{T}{2L}\right) + (n - 1)\left(\frac{T}{L}\right) + .5$

Notice that when T/2L is a whole number, the last page of the book will contain stimulus frames. When T/2L is a fraction, however, the last page will contain response frames and both the last page and second to last page will bear the same frame numbers. In other words, the stimulus frame and the response confirmation will be back to back on the last page. The following examples are presented to illustrate the use of the formulas.

Example A: T = 15 frames
L = 5 levels

This program has 15 frames which are to be presented in five levels or, in other words, five frames to the page.

Total sheets of paper needed = T/L; 15/5 = 3
Total number of pages needed = 2T/L; 30/5 = 6

Formula I is used to determine the numbers of frames to be placed on the first and second pages:

First Page	Second Page
$1 = S_1$	$15/5 = R_3$
$(15/5) + 1 = S_4$	$2(15/5) = R_6$
$(2 \cdot 15/5) + 1 = S_7$	$3(15/5) = R_9$
$(3 \cdot 15/5) + 1 = S_{10}$	$4(15/5) = R_{12}$
$(4 \cdot 15/5) + 1 = S_{13}$	$15 = R_{15}$

Notice that $T/2L = 15/(5 \cdot 2)$ which is a fraction and not an integer. Therefore, formula III is used to obtain the numbers of frames for the last and second to last pages.

Frame numbers calculated for:

Second to Last Page	Last Page
$(15/2 \cdot 5) + .5 = S_2$	$= R_2$
$(15/2 \cdot 5) + (15/5) + .5 = S_5$	$= R_5$
$(15/2 \cdot 5) + 2(15/5) + .5 = S_8$	$= R_8$
$(15/2 \cdot 5) + 3(15/5) + .5 = S_{11}$	$= R_{11}$
$(15/2 \cdot 5) + 4(15/5) + .5 = S_{14}$	$= R_{14}$

The page layout for this 15-frame program will look like this:

Page 1	Page 2	Page 3	Page 4	Page 5	Page 6
S_1	R_3	R_1	S_3	S_2	R_2
S_4	R_6	R_4	S_6	S_5	R_5
S_7	R_9	R_7	S_9	S_8	R_8
S_{10}	R_{12}	R_{10}	S_{12}	S_{11}	R_{11}
S_{13}	R_{15}	R_{13}	S_{15}	S_{14}	R_{14}

Sheet 1 (Pages 1–2) Sheet 2 (Pages 3–4) Sheet 3 (Pages 5–6)

<u>Example B</u>: T = 161 frames (uncorrected); 165 corrected
L = 5 levels

Total sheets of paper needed = T/L; 161/5 = 32 1/5. Four blank frames must be added to make T evenly divisible by L. <u>Corrected</u> T = <u>165</u>, and total sheets of paper needed are 165/5 = <u>33</u>.

Total number of pages needed = 2T/L; 330/5 = 66

Formula I is used to determine the numbers of frames for the first and second pages of the textbook. The corrected T (165) is used in this formula. Results indicate that page one will contain stimulus frames S_1, S_{34}, S_{67}, S_{100}, and S_{133}. Page two will contain response frames R_{33}, R_{66}, R_{99}, and R_{132}.

Since T/2L, or in this case 165/10, is a fraction, formula III is used to determine the numbers of the response frames to go on the last page of the book. The last page will contain response frames R_{17}, R_{50}, R_{83}, R_{116}, R_{149}, and the second to last page will contain the corresponding stimulus frames.

Example C: T = 1000 frames
L = 5 levels

Total sheets of paper needed; 1000/5 = 200
Total number of pages needed; 2000/5 = 400

Formula I indicates that page one will contain stimulus frames S_1, S_{201}, S_{401}, S_{601}, S_{801}.

Formula II is used to determine stimulus frame numbers for the last page because T/2L or 1000/10, is a whole number. The last page will contain stimulus frames numbered S_{101}, S_{301}, S_{501}, S_{701}, and S_{901}.

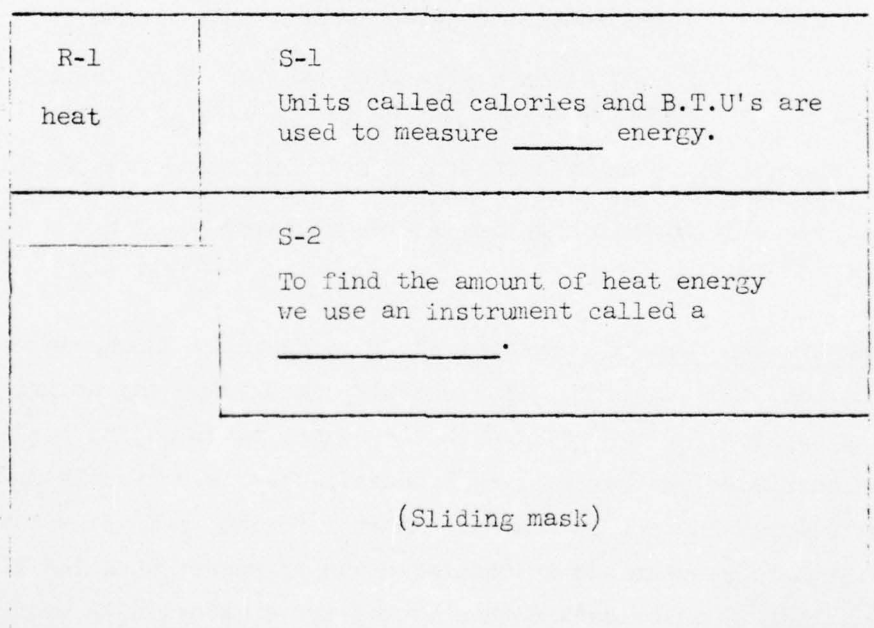
Other Printed Formats. Besides the programmed textbook, several other printed formats are available. For example, each frame may be printed or typed on a separate 3" x 5" card with the answer given on the back and the cards can be bound together by ring binders. This is obviously not a useful format with large numbers in frames. Another format is a variation of the scrambled textbook described in Chapter 6 and is useful when the linear programs primarily described in this manual are combined with branching. A recently published program is a good example of this format.[3]

---

[3]Orear, J. Programmed manual for students of Fundamental Physics. New York: Wiley, 1962.

In still another display mode, the stimulus frames are presented on the two-thirds of the page furthest from the binding and the responses to each frame are placed in the one-third of the page closest to the binding. A sliding device used with this format covers the third of the page containing the response confirmation. Frames are arranged sequentially on a page and as the student progresses from one frame to another, he moves the device down the page revealing the correct response to each frame as he completes it. When the student reaches the last frame on the page, he moves the shield upward again, and uses it on the next page in the program. Figure 2 illustrates this format.

Figure 2. The Sliding Mask Format



It is evident that the nature of the subject matter and age of the students will dictate the format in which the program appears, but all considerations should be subordinated to the idea that the program should teach well and efficiently. The mode of presentation should never compete with this purpose. It is also to be emphasized that no one teaching machine

or display mode will take care of all the programs that will be developed in the future. For special skills it is sometimes useful to favor machine presentation of a program. On the other hand, a display device which is excellent for certain subject matters and with certain trainees may be much less effective when used in a different situation. This chapter has dealt with the most usual kind of programmed textbook. Machine presentation, while important, has not been discussed because the emphasis of this book is on the program rather than forms of automation. For a comprehensive discussion of machine presentation and available teaching machines, the reader is referred elsewhere.[4]

Final Tryout

When all the units of a program have been assembled and have been reproduced in the selected mode, the program should be tried out once more on a group of trainees for whom the program is intended. This tryout is not meant to change any aspects of the program essentially, but to further validate the existing program and to determine its optimal use in an instructional setting. Again, tests should be given to the subjects. Subjects might also be assigned to experimental groups each of which use the program in a different way. This tryout may be used to indicate the best role for the instructor and the organization of the curriculum in terms of the sequence of programmed material, laboratory work, group discussion and lectures.

Only after the completion of all the stages described here, including this last validation stage, can a program stand as a finished product. After the final tryout, the programming director should be able to prepare a manual specifying certain characteristics of the program in detail, describing the principles on which the program is based, indicating the success of the program with a given number of subjects of known qualifications, and identifying specific goals that the program achieves.

---

[4]Kopstein, F. F. et al. An overview of automatic tutoring. Wright-Patterson AFB, Ohio: Training Psychology Branch, WCLOPTR Aero Med. Lab., WADC (ARDC) January, 1959.

A survey of the industry, 1962. Washington, U. S. Govt. Printing Office, 1962. OE-34019.

The Program Manual

When a program is published for operational field use, it should be accompanied by a manual which provides the user with adequate information about the objectives of the program, the procedures involved in its development, suggestions for its optimal use, and descriptions of what might be expected from the program based on its previous effectiveness. The manual should be written to be meaningful to personnel in charge of schools and training organizations. Users in operational educational and training situations will have only the information supplied in the manual and will rely on it in making decisions concerning the program. The manual should be updated and revised at appropriate intervals with further use of the program. If research and development are to be conducted in connection with the program, a supplementary manual will be required for research personnel.

It is recommended that the following items be considered in the preparation of a program manual. The items listed can also serve as a check-list to help insure that a program has adhered to certain standards of quality.

Specification of Objectives:

1. The objectives should be stated in specific behaviors which can be observed in student performance. It is insufficient to say that a student should understand and be able to apply Ohm's law; situations must be specified which indicate samples of performance. The program manual should indicate how the training objectives were derived, and should refer to appropriate curriculum and subject matter sources.

2. It is further desirable that the manual refer to specific achievement tests which measure the terminal performance taught by the program.

3. If the programming procedure has suggested new ways of presenting the subject matter, these innovations should be described, e.g., if the terminal behavior is best attained by an unorthodox subject matter arrangement, the merits of this arrangement should be explained.

Program Prerequisites (Entering Behavior):

1. The knowledge and skills required by the student in order to begin the program should be clearly stated. If available, programs or other courses of instruction which prepare the student for the program under consideration should be indicated.

2. The aptitude levels of the students for whom the program is designed should be stated. These aptitude levels should be stated in terms of generally recognized aptitude tests.

Program Validity:

1. Achievement test data should be reported to indicate the extent to which the program has accomplished its instructional objectives. These data should be reported in quantitative terms indicating the mean and standard deviation of group proficiency test scores.

2. The test(s) employed to evaluate the program should be either an appropriate standardized achievement test currently in use or a specially prepared test which adequately samples the terminal behavior.

3. The content of the achievement test should be described accurately and in detail, indicating the kind of performance it measures and the kind of performance it does not measure (see Specification of Objectives, Item 2).

Test Conditions and Student Sample:

1. The conditions under which the proficiency test was administered should be described, e.g., the time interval between finishing the program and taking the test, whether more than one test was given to measure retention of the subject matter, and whether precautions were taken to avoid prior exposure to the test. If the subject matter is one in which a student could have had little prior exposure, administration of the test after the program is sufficient. If, however, the subject material is one which many students might have learned before taking the program, alternate forms of achievement tests should be given before and after program administration.

2. The sample of students on which the data have been collected should be described in detail, e.g., their prior training, background and aptitude level. Indications should be given of the extent to which the student sample departs from the kind of student for which the program is recommended.

3. The characteristics of the school or training situation in which the data have been collected should also be clearly described.

Program Effectiveness:

1. Indication should be given of the efficiency of the program as an instructional tool. Frequently this can be given in terms of the time taken to attain the terminal behavior and the amount of supplementary instruction recommended for use with the program, e.g., amount of instructor time required and the amount of additional student work required.

2. Steps should be reported which indicate the effects of the program upon student motivation and work habits. The technique of programmed instruction promises to encourage more interest in the subject matter and better habits of concentration. Data on such a hypothesis should be presented as quantitatively as possible and as the result of controlled study.

3. The extent to which the program enlarges student knowledge should be indicated, e.g., if the program teaches more than is usual or can be used with lower aptitude, age and background levels than is usual.

Administrative Considerations:

1. The manual should describe the way in which the program is to be used in conjunction with other means of instruction such as lectures, discussion groups, or laboratory work. Indications should be given of the amount of time the student should spend on the program each day in relation to these other activities.

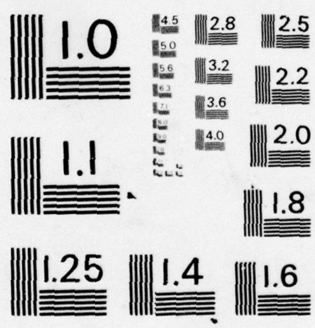
2. If use of the program necessitates other than the usual classroom arrangement, such recommendations should be specified.

AD-A031 367 PITTSBURGH UNIV PA PROGRAMMED LEARNING LAB F/G 5/9
A GUIDE TO THE PREPARATION OF PROGRAMMED INSTRUCTIONAL MATERIAL--ETC(U)
OCT 62 J I TABER, R GLASER, H H SCHAEFER AF 33(616)-7175

UNCLASSIFIED NL

3 OF 3
AD A031367

END
DATE FILMED
11-76



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Summary

The production of a program is usually a team effort. This chapter describes one such idealized team. The programming staff described here is headed by a programming director and consists of: (a) a subject matter specialist who outlines the terminal behavior, (b) programmers who prepare the frames, (c) a training specialist who specifies the entering behavior of the learner, (d) three editors who review frames from a psychological, linguistic, and subject matter standpoint, respectively, and (e) a make-up director responsible for the visual aspects of frames and the program's artwork and appearance. Although these tasks need not be filled by different individuals, the quality of the program is likely to be improved when several persons have worked on and reviewed the frames.

The development of a learning program may be a complicated and lengthy process. Before production can get underway, the goals of the program need to be specified in a detailed listing of terminal behavior and agreed upon by the subject matter expert, the programming director, and the program sponsor. Administrative details in setting up the enterprise must also be attended to, and programmers must be trained. Programmer training may take some time in itself and can best be accomplished by having the programmers begin writing frames as soon as possible.

Program production consists of a series of steps which can be summarized as follows:

1. Initially, programmers prepare frame sequences leading to the specified terminal behavior. Typically, these sequences will be reviewed by the programming director and tried out on subjects. The sequences are then revised based on the subjects' responses and tried out again with new subjects. The process of tryout and revision continues until errors on the frames are minimal.

2. Units of frame sequences are edited by the linguistic, psychological, and subject matter editors. The make-up director also examines the frames and makes recommendations regarding program format, frame layout and illustrations, and extra panel materials. Suggestions of the editors and make-up director are reviewed by the programming director and implemented upon his approval.

3. Program units are tried out on a carefully selected sample of subjects and a test of terminal behavior is given to assess the program's effectiveness in teaching. Where indicated by the subjects' responses and test results, subject matter is reorganized and additional writing, revision and tryout conducted.

4. When the tryout indicates that the program achieves the terminal behavior, the program is carefully proofread and edited again. It is then put together in the format selected for its final form and reproduced.

5. The program in its final form is tried out on a group of subjects representing those for whom the program is intended. This tryout serves to validate the program and to indicate its optimal use in an instructional setting.

6. A manual is prepared to accompany the program and to aid program users. The manual should specify the program objectives, prerequisites, validity, effectiveness and procedures for use.

PART IV

RESEARCH AND DEVELOPMENT

Chapter 8: Implications for Research, Development, and the Conduct of Training

The introduction of programmed instructional materials raises a number of considerations for research and development in training and for the conduct of instruction. This chapter considers some of the tasks and problems that appear to result from the impact of programmed instruction. Implications are considered for research and development, and certain consequences in the carrying out of training operations are pointed out.

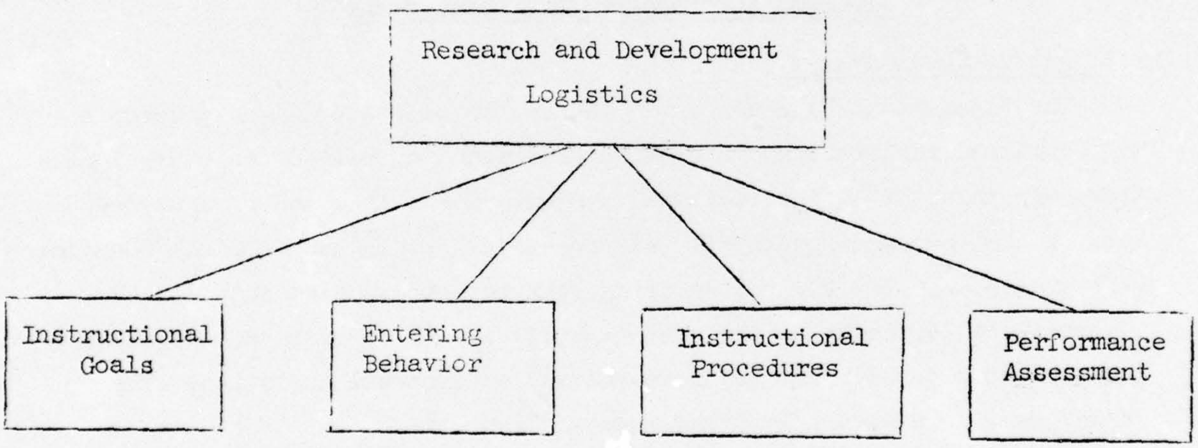
Problems for Research and Development

The Instructional System

The issues that have arisen in the course of research and development in programmed instruction can best be described in terms of an over-simplified conception of an instructional system. The system can be analyzed into the following components: (a) educational goals and terminal behavior (the system objectives), (b) entering behavior (the system input), (c) instructional procedures (the system operator), (d) performance assessment (the output monitor), and (e) research and development logistics. The structure of the system is diagrammed in Figure 1.

The system is initiated with the specification of the goals of instruction. These goals constitute the objectives and the purpose for which the system is to be designed. The main input upon which the system operates is the entering behavior of the student. This consists of the repertoires, aptitudes, and educational background with which the instructional process begins. The operations of the system include the actual instructional procedures and experiences which are employed to guide and modify behavior. The final phase in an instructional system is quality control, that is, assessment of the extent to which the terminal behavior has been achieved by the student with respect to the specified instructional goals. For the most part, the instructional system proceeds through the phases in sequence, but it also has many feedback loops and subsidiary inputs, and information obtained in each phase is used to monitor and correct the output of the

Figure 1. The Components of an Instructional System



preceding phase. For example, measurement of the kind of performance achieved can provide information for redesigning instructional procedures, and information on instructional procedures can interact with the characteristics of the entering behavior. Feeding into all phases are the results of research and development. Implementing the results of the fruitful interplay between research and development and the operating aspects of the system involves important logistical considerations.

This very brief overview of an instructional system provides a basis for considering the impact of programmed instruction upon each of the component phases. The following discussion is concerned with the implications of presently constituted programmed learning procedures in each aspect of the instructional system. Programmed instruction is defined here in terms of the characteristics of programmed materials and devices currently being used.

Terminal Behavior (Instructional Goals)

Although much time has been spent on analyses of curricula and training objectives, less time has been devoted to pinpointing the kinds of performances that students must display to indicate achievement or approximate attainment of these goals. There are several reasons for this, one of the most obvious being that not enough is known about complex behaviors to allow a specific analysis. A second reason, however, is that the generality of instructional procedures has not forced the delineation of attainable performance standards. (It is interesting to note here that when psychologists have turned their attention to training research in the military, the lack of explicit training objectives has been a primary concern and numerous attempts have been made to develop techniques of "task analysis" for behaviorally specifying performance requirements.)

In contrast, the preparation of a programmed instructional sequence requires the programmer to know where he is going and what kind of performance he wishes the student to achieve at the end of the sequence. This is not to imply that an instructional procedure need be a rigid technique which trains all students to do the same thing in the same way. It has been stressed throughout this manual that in order to optimize transfer, instruction must occur in a variety of environments, one of these being, where applicable, programmed self-instructional procedures. Recognition that the end results of instruction need to be carefully specified in terms of human performances has forced the psychologist and the educator to acknowledge that an appropriate terminology for behavioral description, a taxonomy of behavior, is not available. At present, many training researchers assign high priority to the development of a taxonomical scheme for specifying the properties of behavior to be learned. In this respect, the relationship between task properties and the characteristics of the learning process is an important research problem.

Another aspect of instructional objectives is the question of performance limits or limits of learning. Presumably, as training techniques become more effective, more of the abilities of human beings will be tapped, and new levels of performance will be reached. Programmed instruction with its emphasis on the shaping of behavior beginning with available responses

and proceeding to stated objectives, can more closely approximate performance limits. This can be done, for example, by teaching presently taught subject matters at lower aptitude levels and by teaching aspects of behavior that have themselves been classed as aptitudes, e.g., spatial relations and speed of perception. Indeed, for certain purposes a test of a good program might be how far down in aptitude level it can be used.

Entering Behavior

The behavior the student brings to the instructional situation is the raw material with which teaching begins. Programmed instructional procedures should force an evaluation of these initial behaviors resulting from prior background and preparation so that they can be used as the basis from which to guide student performance. A programmer must know what student behavior he can count on before he can write the initial steps.

With respect to an entire learning sequence, the notion of entering or prerequisite behavior relates to the problem of the ordering of subject matter content. It would seem that many things could be learned if the necessary prerequisite behavior exists. The establishment of appropriate hierarchies of subject matter learning can be explored systematically using programs in which sequential patterns can be experimentally manipulated.

Instructional Sequences

Sequences of graded subject material with which the student works are the heart of the instructional process. Instruction begins with the student's entering behavior and ends in the terminal behavior with which he leaves the situation. Between these two points, instructional manipulations and learning experiences take place which guide the student. The behavior elicited from the student by the teaching situation can be called auxiliary behavior. The instructional process is concerned with utilizing auxiliary behavior to approximate desired educational objectives. This process involves determining, for various stages of learning, the subject matter with which the student must work and the kind of responses that he must make.

Currently, programmed instructional sequences are constructed, for the most part, on the basis of limited knowledge from the science of learning plus a good deal of ingenuity and intuition. There is a danger that, under practical pressures and with the lack of trained personnel, program construction will settle upon certain rote rules. Knowledge of learning principles on the part of programmers, however, should foster flexible program development and facilitate feedback to basic laboratory questions. In any event, the empirical nature of the enterprise with its emphasis upon tested sequences which result in particular subject matter performance for particular student populations, can contribute significantly to training.

As has been indicated in this manual, the basic structure of present day programmed instructional sequences is a gradual progression of behavioral steps which take the student to the attainment of a complex subject matter repertoire. The characteristics of these sequences are the essence of programmed learning and require intensive study. The optimal characteristics of these instructional progressions, both with respect to the stimulus materials displayed to the student and his interaction with them, is thus a primary objective of research and technology. Some of the important aspects of such instructional sequences that are open to investigation are considered on the following pages.

Size of Step. There is no special rationale for the short, two or three sentence frames currently in vogue except, perhaps, that more frequent responding offers the possibility for surer control over the subject's behavior. The same principles of learning might be incorporated in much grosser units if these were the most effective way to attain the desired terminal behavior. It should be noted, however, that the so-called "spoon-feeding" which the small steps seem to represent is often more apparent to the subject matter expert reviewing the program than it is to the student taking the program.

The meaning of "step" and "step size" is not precise and research and development efforts should be directed at defining the nature of step. A step may be defined, for example, in terms of the probability of a correct response; thus small steps result in a high probability of correct responding

as one proceeds through a program. Step size may also refer to the amount of material the student must read before making a response, or to the number of responses he must make before knowledge of performance is given. It would be helpful to have a behaviorally definable optimal "bite" which would be maximally efficient, such bites would probably be different for different subject matters and for different entering behaviors. It might also be useful to build a teaching machine which adapts the step size for an individual. At the present time, uniform steps for all students are most expedient from the point of view of program construction. The advantage to be gained by individual adjustment merits further research and development, however, particularly in relation to other step properties.

Programming Richness of Experience. This manual has indicated that a rich program should permit the student to work on a subject matter in a variety of contexts. Keen discriminations and the ability to differentiate and generalize between subject matter concepts can be established in this way. Graded programmed sequences should be able to teach discrimination and generalization between classes of concepts. To provide rich experience, a programmed sequence should expose the student to many specific situations in order to leave him with a repertoire he can generalize to a variety of situations, i.e., so that he has wide experience in using the general concept involved. Investigation is needed concerning the properties of student response to a graded sequence of instances which lead to effective use of the generalized and more abstract concept or rule involved.

Analysis of Knowledge and Task Structure. The analysis of the knowledge domain into units which will form the building blocks of the program, is a problem in constructing a learning sequence. The structure of a program sequence should be a joint function of both the structures of the task or subject matter domain and the behavioral characteristics of the sequence which best facilitate retention, transfer, and so forth. As the behavioral scientist discovers more about learning, appropriate learning structures can be incorporated with the structure of the knowledge domain to produce a more ideal arrangement for the acquisition of knowledge. Such a joint analysis may result in the revision of knowledge structures and task presentation sequences.

The Form of Student Response. There has been much controversy with regard to the manner in which a student should respond to a program and many studies have sought to contrast the effectiveness of constructed responses and multiple-choice responses. No conclusive differences have so far been found, perhaps because this is something of a pseudo-problem. The assumptions of programming procedures do not make one kind of responding more correct than any other. Response mode would seem to be a function of the desired terminal behavior. In the course of an instructional program, however, the form and encoding of responses can be an important matter, since some forms of response are easier to code, evaluate, and automate than others. An important research and development problem would seem to be the determination of the degree of generalization between different forms of response to subject matter stimuli.

Generalization in this sense is related to transfer, i.e., the adaptability of responses that are learned in one situation to new situations. Studies with programmed instructional sequences should permit the identification of the properties of sequences that can produce transferable behavior. Rather than search for transferable subject matter elements which may be useful in instruction, such studies might well examine the production of transfer through practice with graded sets of experiences containing a variety of subject matter characteristics. Thus the ability to generalize to new experiences would be taught by providing practice in such behaviors, as well as reinforcement for generalizing.

Implicit responding (i.e., responding to one's self) is one form of response which needs to be considered further in programmed instruction. Practically all existing programs require overt responses, primarily because these permit the constant monitoring of student behavior. However, much efficient behavior and much of what is called thinking occurs without apparent responses. Although some experiments have studied explicit responding to programmed learning sequences, results are insufficient for any conclusive statement and further studies should be made. One study in progress permits the student to make implicit responses, but aperiodically requires him to respond overtly to particular test frames. The constant possibility of being asked to make an overt response may permit teaching

rigorous implicit responding in a manner which might be described as "thinking things out."

Retention of Basic Skills. The general effectiveness with which basic skills are taught at the present time can probably be improved by developing training curricula which apply the concept of programmed instruction. Many questions will arise in implementing such curricula. Studies are required to determine how much and what kind of basic knowledge students retain as a result of instruction, i.e., how much and what kind of practice and review results in some standard of retention or facility to relearn. These studies should consider specific kinds of tasks, specific kinds of training, and individuals with particular life patterns. The effects of practice need to be identified so that practice can be used knowledgeably and under the most effective conditions.

Rate of Learning. A great deal has been written about the fact that with programmed instructional techniques the learner can proceed at his own rate. This is one of the substantial advantages of programmed self-instruction, especially in view of a de-emphasis of lock-step curricula and the increasingly prevalent notion that for different individuals equal training accomplishment can take unequal amounts of time.

From another point of view, programmed instruction can provide an opportunity for not permitting students to proceed at their own rate; it can be used to pace them so that they learn at a fast rate, and learn to work at a fast rate whenever this is desirable. Under the pressure of an external or self-imposed deadline, most individuals work quickly and their final products often differ little from those produced in a more leisurely manner. Although little basic research has been done on pacing and response speed during learning, these aspects of programmed instruction should be considered for both technological and scientific implications.

<u>Response Feedback and Reinforcement</u>. There seems little doubt that a significant aspect of educational technology will be the management of reinforcing operations. A teaching machine or programmed textbook is a procedure which provides for a certain kind of management of reinforcement. For applied research and development leading to an instructional technology, the main question is not what reinforcement is, but how it operates. Answering this question necessitates specifying the variables which determine the effectiveness of certain reinforcing operations in achieving desired instructional objectives.

Studies with programmed sequences which have varied the amount and delay of response feedback, have shown few differential effects. Such findings should prompt further investigation of the role of feedback and reinforcement in efficient instruction. As has been pointed out in this manual, it is possible that with humans responding is often reinforcing in itself, at least when optimal instructional steps are used. When a program sequence is constructed for use with a large number of subjects, however, steps may not be optimal for an individual learner and he may also require confirming feedback. Recent work with programmed instruction suggests that with high aptitude students the aspect of a program which is most reinforcing is going on to the next step. For these individuals, response confirmation may be minimally reinforcing because they have a prior history of being right most of the time. With low aptitude individuals, on the other hand, the important reinforcing event seems to be the feedback that certain responses are correct on which they have previously had a history of failure.

Programmed sequences can, perhaps, lead to more self-reinforcing responses if they are set up so that the individual can select that step which is maximally based on his past performance. The term "adaptive programming" has been used to describe this kind of fine adjustment to individual differences and branching programs, for example, are an attempt to achieve such flexibility. Similarly, certain computer-based instructional systems employ the adaptability and speed of a computer to adjust to individual instructional requirements. Research and development are needed to investigate procedures which can individualize a particular instructional situation as much as necessary for efficient instruction.

Reinforcing events occur in different frequencies and in different patterns during the course of learning. For example, studies of the effects of the pattern and scheduling of reinforcing contingencies have indicated that behavior matches the ratio of reinforcement to non-reinforcement of a learning task. Thus the probability of a response will approach the probability of reinforcement. (To illustrate, if 90% of the English nouns encountered by a student form their plurals in "s" and 10% use "n," the student would be expected to form the plural of newly encountered nouns with "s" about 90% of the time.)[1] The concept, operations and relationships involved in reinforcement are central in programmed instruction and the variables involved demand extensive and intensive analysis.

Performance Assessment

The empirical manner in which programs are constructed has required that programs be accompanied by carefully prepared assessment tests. These tests serve two purposes. First, they present a sample of the terminal behavior which the program was designed to teach. Second, they show what the expected achievement might be based on previous program use. Although the final frames of a program also sample the subject matter situations which the student must handle at the end of the program sequence, a relevant achievement test can be considered as another sample from the universe of subject matter content. It is often said that the achievement test should permit the student to transfer his knowledge. This should be true only to the extent that transfer is defined as an instructional objective, or can be expected on the basis of the student's entering background and aptitudes.

The specificity of terminal objectives required by programmed instruction brings to light some current aspects of achievement testing in general. Underlying the concept of achievement assessment is the assumption of a continuum of subject matter competence ranging from low proficiency to high proficiency. A student's performance on a test falls at some point along this continuum and can be compared to the behaviors which define the points

---

[1] Estes, W. K. Learning. Encyclopedia of Educational Research, (3rd ed.) New York: Macmillan, 1960. Pp. 752-767.

of the skill continuum. Similarly performance levels can be established at appropriate points in a course of instruction and the behaviors which define each level of proficiency can be identified and used to describe the subject matter skills which a student is capable of performing at a particular level. In this sense, performance measures can be "content-referenced," that is, the performance of an individual can be compared with specific subject matter skills.

In contrast, achievement is typically expressed in terms of "norms" which permit comparing a student's performance with that of other individuals. In current testing practice, an individual's relative standing is often the primary information obtained, and no reference is made to subject matter content. "Grading on a curve" is a notorious example of the extreme of this practice. Norm-referenced measures are certainly useful and indicate that one student is more or less proficient than another, but do not provide information about how proficient either of them is with respect to the terminal behavior of instruction. With the increasing application of programmed instruction, there should be an increasing use of content-referenced scores; measurement procedures for these kinds of scores will be needed and should be developed.[2]

Individual Differences and Aptitude

It has been pointed out that the concept of programmed instruction focuses attention upon getting the student from here to there rather than upon the aptitudes that allow him to do so. In programming the problem of individual differences becomes a matter of defining the entering behavior of the student with which instruction must begin. It may be that the student can not perform the behaviors needed to begin a particular instructional sequence, so that it will be necessary to bring him to the level of proficiency required before proceeding with the sequence. The specification of entering behavior is the process of determining what the student can do

---

[2]For a further discussion of content-referenced scores, see Glaser, R. & Klaus, D. J., Proficiency measurement: assessing human performance. In R. Gagné (Ed.), Psychological principles in system development. New York: Holt, Rinehart and Winston, 1962. Pp. 419-474.

initially that can be used to get him to the terminal behavior, and whether he can get there if he begins with his current repertoire of behavior. Thus the individual's entering behavior will recommend one instructional sequence rather than another. Put in this way, the instructional situation becomes an engineering and management enterprise in which interaction between the raw material and the educational process can be used to predict the practical possibilities for educational accomplishment. Essentially, in programmed learning, aptitudes can be defined as those initial behaviors with which the instructional process must start. There is much research needed along these lines, since the relationships between the general aptitude of measured intelligence and the way in which an individual learns have not been studied in a way which permits ready conclusions.

A relevant study concerning the effects of programmed learning has indicated that programmed instruction raises the achievement level of individuals who would get low test scores with other instructional means, thus reducing the total spread of achievement compared with the variability under conventional instruction. In effect, this results in decreasing the predictability of such indicators of academic performance as aptitude tests, since test validity coefficients are a function of the variability of the measures obtained. Of course, this reduction in variability may disappear or perhaps variability will be increased as higher achieving students are permitted to learn more.

Since a programmed instructional sequence is an experimental "apparatus," it may be very useful in studies of individual differences. It should be possible, for example, to teach certain subjects to bright students, carefully identifying the behavior they have before coming to the program and the achievement with which they leave the program. It should then be possible to select a group of low aptitude individuals who have similar entering behavior and attempt to take them to the same level of achievement as the bright students. Such a study would vary the steps and manipulations required in the program. It may be possible in this way to identify more rigorously than before the differential characteristics of the learning process for these groups of students.

Other research on programming has attacked the problem of constructing programs to produce certain behaviors which might generally be classed as aptitudes, that is, the kind of behavior measured on aptitude tests. For instance, instructional programs are being investigated that "teach" pitch discrimination and spatial visualization (translating between two-dimensional and three-dimensional figures). Programmed instruction, then, with its emphasis on production of behaviors in the individual may permit some inroads in analyzing behaviors which are not usually part of a training curriculum and may lead to a more rigorous definition of "aptitude."

Machines, Automation, and Simulation

It has been repeatedly stressed that the programming of subject material is the essential ingredient in programmed instruction, while machine aspects, however desirable, are supplementary. This emphasis has been necessary because of the rash of hardware that has appeared for which no programmed materials are available. Moreover, a number of recent experiments have indicated that for many of the subject matter skills presently being taught, the programmed text is at least as effective as machine presentation. As a result, there is a current tendency in many quarters to discount machine presentation.

Nevertheless, the possibilities for automation should be considered in the course of research and development. Although some subject matters or educational levels may not require automation, it has great potential in keeping the programmed learning enterprise inventive.[3] It seems likely that instrumentation might be relatively simple in the early stages of learning, but more complex situations requiring extensive simulation and appropriate automation may be desirable at later stages of learning where complicated problems are to be encountered.[4] Computer simulation of complex problems, for example, might be considered in the construction of programmed instructional sequences.

---

[3] Coulson, J. E. (Ed.), Programmed learning and computer-based instruction, New York: Wiley, 1962.

[4] Gagné, R. M. Simulators. In R. Glaser (Ed.), Training research and education, Pittsburgh: University of Pittsburgh Press, 1961. Pp. 223-246.

Prototype Model Instructional Systems

In concluding this section on problems for research and development it is suggested that a significant undertaking would be the development of working instructional models. Such tangible models can be very effective in changing behavior patterns which are difficult to change by other means. As a result of experimental study, model instructional systems should be developed which sample training problems for a wide variety of tasks and aptitude groups. Tangible curricula based upon the concept of programmed instruction, which can be reproduced by others and have been rigorously evaluated to determine their effects and the extent to which they attain stated educational objectives, seem to be a first order of business for research and development in training.

Operational Considerations For An Instructional System

Throughout the course of this manual, it has been pointed out that the concept of programmed instruction has significant implications for training practice. However, for these implications to be realized a programmed instructional course should not be used in a rigid training system, but rather in one which permits the impact of the concept to take effect. A flexible environment is necessary which permits any desirable changes in the training system to develop, changes such as individual student pacing, revised classroom structures, more effective use of instructor time and increased specificity of achievement standards. The concept of programmed instruction should also result in a de-emphasis of the present orientation around educational media, such as films, television, and language laboratories, and should place emphasis upon a process of instruction in which the special advantages of various media can be assessed. One of tne major advantages of using programmed devices in training systems is that they facilitate reorganizing and restructuring the curriculum and should lead to the appropriate balance of programmed self-instructional materials with other instructional procedures.

Training Objectives

In practice, a distinction should be made between training goals and the terminal behavior of instruction. Training goals are necessarily long range in scope and involve many considerations of ethics, philosophy and policy inherent in the overall operational training setting. The discussion in this manual, however, has been limited largely to instructional technology and has emphasized the need for methods by which instructional objectives can be determined and described in order to assure their attainment in an instructional system. In contrast to the broad goals of a training system, terminal behavior refers to the performance that a student should display at the end of a specific instructional situation. Such specificity makes it possible to set minimum levels for attainment, and maximum levels can be left for individual initiative. When a minimum level is established, it is the task of the instructional system to get most individuals to that point. In military and industrial training, these minimum levels are those required for the optimal functioning of man-machine field systems, and the instructional situation must be arranged to permit attainment of these levels of performance.

Programmed instruction emphasizes the importance of terminal behavior as the end product objective of a particular instructional situation. The procedures of instructional technology should result in definable changes in student behavior which approximate this end product. In order to accomplish this, the final course requirements for the trainee must be precisely specified insofar as possible. The techniques for task analysis and for the development of personnel requirements which originated primarily in the military setting, are an attempt to develop methods for specifying performance objectives and should be useful here.

Training Input

The behavior students bring to the instructional situation is the raw material input of the training system. Programmed instructional concepts emphasize the importance of assessing and making explicit the initial behavior of the trainee so that it can be used as the basis from which to guide student performance toward terminal behavior. Entering behavior is usually assessed by means of aptitude and achievement tests which are used

for student selection and placement. Such tests are often employed to weed out individuals who are unlikely to attain the specified terminal behavior under the particular training conditions, and to predict performance in an established course of training.

Considering the training system as a whole, it should be possible to determine the best combination of instructional objectives, input behavior requirements, and instructional procedures in order to achieve overall organizational goals with maximum efficiency. Since these aspects of the instructional system interact, test selection standards and the time, cost, and characteristics of instruction can be varied to permit optimal functioning of the system. In military planning, for example, the tasks assigned to the various personnel who contribute to the accomplishment of a particular mission may be reorganized so that more or less rigid training standards are required. Such a reorganization can permit intensive training of specialists on only particular job aspects while less technical tasks can be assigned to individuals who have less time available for training.

In reviewing the behavioral input as a part of an instructional system, it is possible to treat it as a quantity that can be varied with changes in the necessary training. Programmed instruction with its emphasis on entering behavior should serve to increase the feasibility of specifying pre-training requirements and actual training requirements (costs and time) in order to accomplish certain objectives.

Instructional Procedures

The instructional process is concerned with the utilization of the student's behavior to approximate desired training objectives. One means of facilitating this process is by programmed instructional procedures. This manual has discussed the psychological rationale behind these procedures, and while precise specification is limited by the lack of psychological knowledge in analyzing complex behaviors, it seems possible to outline, in part, some of the processes involved in the guidance of behavior through instruction. Certain aspects of the learning process have been known for some time, but until the development of programmed

instruction, attempts have not been made to apply them so directly to instructional situations.

The notion of stimulus control is an important feature in the guidance of learning within an instructional situation (Chapter 3). At the beginning of a learning sequence, subject matter stimuli are used to evoke responses that are already in the initial repertoire the student brings to the teaching situation. During instruction there is a gradual transfer of control to new subject stimuli. A basic instructional task is to get the student to emit response increments which move in the direction of the terminal behavior. Response prompting is a means to this end. In the course of instruction there should be a withdrawal of supporting prompts so that the student eventually responds to situations defined in training objectives.

The management of reinforcement is of primary importance. Preferably, immediate and positive reinforcement should be arranged in order for behavior to be efficiently learned. The effects of discrimination, generalization and extinction should also be considered in planning an instructional situation. An awareness of these processes makes it possible to minimize interference in the course of learning and to understand the possible reasons for lack of transfer of training. Practice and review are also important components of instruction, and the conditions for practice described earlier (Chapter 6) should lead to effective learning and retention. The general application of these aspects of learning can contribute to the design of overall training systems as well as to the construction of particular programmed materials.

Performance Assessment

It is necessary to assess performance within a training system in order to determine the degree to which an individual has attained the criterion behavior. Individual performances should be compared to the behaviors which define points along the appropriate skill continuum. A particular job usually involves several grades or levels of skill. Thus, a machinist, for example, can be categorized as an apprentice, a journeyman, or a master of his trade. The specific behaviors implied by each of these levels of proficiency can be identified and used to describe the specific tasks a machinist is capable of performing when he achieves one of these skill levels.

The emphasis of programmed instruction on the attainment of particular behaviors, encourages proficiency measurement with respect to such specific job standards. Although many assessment procedures in training are referenced in terms of norms or group curves that evaluate an individual's performance relative to the performance of other members of a group, an effective training system should require performance assessment measures that provide explicit information about what the individual can or cannot do.

Technology in Training

As a result of the impact of programmed instruction it is becoming increasingly more possible to consider instruction in general as a technological endeavor. Ultimately, specific training practices will be developed out of the findings of a science of learning and out of appropriate research and development concerned with instructional systems. To move towards this end, research and development endeavors are needed concerning all aspects and functions of a training system. *Instructional programs* of the kind described in this manual provide both practical training procedures and reproducible instructional procedures for experimentation.

A research and development capability should be an essential part of an effective training system. Research efforts should be directed towards the further study and application of exploratory research in order to foster the development of techniques which can be incorporated in instructional practices. This work should involve research designed to further basic knowledge in the science of learning, as well as research and development designed to implement and evaluate new and changing practices in instructional technology.

Conclusion

When there are problems to be solved, a new procedure or device may contribute to their solution. There is the danger, however, that narrow concentration on the specific features of the initial crude aspects of the newly developed technique, to the exclusion of the underlying concepts involved, can focus attention on the tool without concentrating on the solution of the problems. The present products of the concept of programmed instruction are not in this kind of immediate danger, although they will be in a few years if research and development on implementing the concept are not pursued. With this in mind, the major portion of this chapter has explored some of the research and development problems that have been indicated by work to date.

In general, the significant implications of programmed instruction for training and training research and development can be summarized as follows:

1. The concept of programmed instruction is of primary importance in contrast to its present crude implementation.

2. Programmed instruction represents a step in the engineering application of science to educational practice.

3. As a technological application, programmed learning is required to make a practical difference or be replaced.

4. The attempt to make a practical difference in human learning will feed back to the behavioral scientist and open up many basic research questions.

5. Programmed instruction focuses attention more than ever before on the essential ingredient of training--the instructional procedure employed to guide student behavior from present skills to task proficiency.

6. Programmed materials can increase the effectiveness of training because as tangible, reproducible devices they can be severely tested, evaluated, improved, and redesigned.